



TELESCOPES: EYES ON THE UNIVERSE OUTREACH TOOLKIT MANUAL

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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>.

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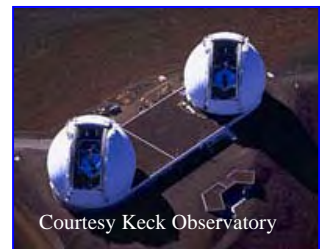
Introduction: Telescopes: Eyes on the Universe ToolKit

Amateur astronomers use telescopes to allow us to directly experience the universe.

NASA scientists use telescopes to allow us to understand 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.



Amateur astronomers provide the public with the often life-altering experience of directly observing the detail of Saturn's rings, the swirling clouds surrounding star nurseries, the nebula expelled from dying stars, and the light, traveling for eons, arriving from a distant galaxy.

As our visitors observe these wonders, they also ask many questions about what they see, or what they don't see! Why does the image of the Moon look upside-down? Why doesn't it look like the photos? What power is your telescope? Can you see the flag on the Moon? Where are you looking? Why isn't it in color?

NASA uses not only optical telescopes, but also telescopes sensitive to other wavelengths of light. What do these other kinds of light, or energy, tell us? Using colors we can see to represent energy our eyes cannot see, NASA scientists communicate through images what the other wavelengths of light from the universe tell us. What would the universe look like if our eyes could perceive infrared light? Or radio light? NASA uses telescopes that can perceive these kinds of light to reveal what our eyes cannot see.

This ToolKit includes materials and activities to prepare your visitors for their observing experience and enhance their understanding at the eyepiece.

Summary of activities and resources:

1. **PowerPoint “How Telescopes Changed Our Understanding of the Universe”** to introduce how telescopes answered many of the questions humans have asked for hundreds of years.
2. **“Telescopes from the Ground Up”** website that discusses the history of the developments in telescope technology.
3. **Activity: “Ready to Observe?”** This set of activities helps answer common questions we get at the telescope and provides tools to help your visitors understand what to expect and how to enhance their experience: Why don't I see any color? Where are you looking? How much of the sky are we seeing in the scope? Why is the image upside down? Includes an exercise to illustrate averted vision.
4. **Activity: “What Power is your Telescope?”** Using a few simple props, show the basics of how telescopes work. Includes quick, simple demos that can be done at the telescope.
5. **Activity: “Why Doesn't It Look Like the Photos?”** A set of activities to show why images we see in the telescope do not look like the pictures in magazines. Why NASA needs different kinds of telescopes to help us understand the universe.
6. **Activity: “Can You See the Flag on the Moon?”** Activities to show how much detail you can expect to see in the telescope and the difference between resolution and magnification.

In general, there are activities in this ToolKit appropriate for ages 6 to adult.

Special thanks to Terry McLawhon of the Tar River Astronomy Club in North Carolina for suggesting the name of the ToolKit.

Refractors vs. Reflectors

This ToolKit does not address the difference between reflector telescopes and refractor telescopes (telescopes with mirrors and telescopes with lenses) or about other differences in telescope design.

Experience has shown that those people who are intending to purchase a telescope are the ones most likely to have an interest in the various types of telescopes. There are already substantial resources readily available that discuss the variety of telescopes and factors to consider in choosing a telescope, so this ToolKit does not attempt to duplicate those resources.

This ToolKit is about helping the public better enjoy and appreciate their observing experience as they view the universe through your club members' telescopes. So, this ToolKit addresses those questions most often posed to amateur astronomers at public events regarding what telescopes can do and why visitors see what they see.

Thanks to the ToolKit Testers

NASA and the ASP wish to thank the members of the astronomy clubs around the country who took the time and made the commitment to test these activities in a variety of settings and with a wide range of audiences. Their dedication and feedback helped to make this ToolKit appropriate and fun for the members of the Night Sky Network.

Astronomy Club	State
Aldrich Astronomical Society	MA
Astronomical Society of Northern New England	ME
Astronomical Society of the Palm Beaches	FL
BackyardAstronomy.org	CA
City Lights Astronomical Society for Students	IL
Darien O'Brien Astronomy Club	CO
Eastbay Astronomical Society	CA
North Houston Astronomy Club	TX
San Angelo Amateur Astronomy Association	TX
San Jose Astronomical Association	CA
Spokane Astronomical Society	WA
Statesboro Astronomy Club	GA
Texas Astronomical Society of Dallas	TX
West Hawaii Astronomy Club	HI

Check the next two pages for suggestions and advice from the ToolKit testers.

Suggestions from the ToolKit Testers

Here are some comments from a few of the astronomy clubs who tested the Telescopes: Eyes on the Universe ToolKit in answer to the following questions.

“If you had just 2 minutes to tell someone in your club about this ToolKit, what would you say?”

Astronomical Society of Northern New England

The activities in this toolkit are really useful for answering common questions that the public asks us at the telescope. The tools are simple to use and make the concepts clear by using visual demonstrations. The activities are fun, and some are even challenging. There are activities useful at star parties, classroom presentations, and at astronomy club meetings. You will love using "Telescopes: Eyes on the Universe".

North Houston Astronomy Club

Ever wonder why telescopes work the way they do? Why they have curved mirrors? Why bigger diameter scopes are better? Then you need to check out the activities in this toolkit. Tools that help you easily convey information about telescopes to the public at star parties and presentations. It contains simple material that is appropriate for all age levels.

City Lights Astronomical Society For Students

I would tell the club no matter what you think you know about astronomy, this kit will not only help you, but it will help teach the public more about our wonderful Universe. It is well thought out and well planned.

Eastbay Astronomical Society

It includes great demonstrations of how telescopes work, as well as some of the most common questions that people will be asking you about telescopes. It also explains a lot about what people will see in the telescope such as how much of the sky they will be looking at, why the image is upside down, lack of color. It will really help get your points across and with far fewer words.

San Angelo Astronomy Association

This is a great kit with a wide range of activities, and excellent for use at a star party or solar viewing where you actually have a telescope set up. Many of the activities can be used one on one, or with groups up to 30 or 40. It covers topics such as how telescopes work, and gives an idea of some of the telescopes in use by NASA and others.

San Jose Astronomical Association

The nice thing about this kit it DIRECTLY talks about a lot of the questions you will get when you show off your members' telescopes.

Spokane Astronomical Society

The field of view card makes a great segue into the wavelength posters. The 90 or so people I presented a few of the demonstrations to loved all parts of it.

Aldrich Astronomical Society

The Telescope Toolkit is a fabulous way to bring home key concepts about telescopes in a classroom environment. Many of the teachers that I showed the kit to wanted to arrange to have a talk in the classroom with the telescope toolkit props. Even students who participated said they learned a lot and had fun with the props and doing the hands on activities!

Texas Astronomical Society of Dallas

This kit has some great activities to help explain, with concrete examples, how telescopes work. One of the simplest, yet most useful ones, in my opinion, is the spoon and the foam with sticks demo. It can be used right at the telescope as a quick way to explain to people how the mirrors of a scope work. The Averted Vision and FOV Cards also work very well at the telescope. Other activities like "How do telescopes work" and "Universe in a Different Light" work as group activities.

Darien O'Brien Astronomy Club

This is an outstanding hands-on education tool for the kid in all of us--from grade-schooler to octogenarian. And it is just a lot of fun! Once you use this ToolKit, you will definitely have a new appreciation for what you see when you look at a Hubble Space Telescope photo or what to expect the next time you look through an eyepiece.

“If you were to give advice to other clubs regarding this ToolKit, what would it be?”

San Angelo Astronomy Association

Watch the training video. Go through the materials a couple of times with a practice person before you use it on a group.

Eastbay Astronomical Society

Ensure that [your club] members get a chance to see the demos - since they will like them and be encouraged to use them. Best will be to use them at events where members will be, like star parties, since once a telescope operator sees someone else use the demos to address the common questions they'll want to use them themselves. [Our observatory] now has the field of view cards available at each of their main telescopes.

Astronomical Society of Northern New England

Every person doing outreach with a telescope should have a Field of View card, the Averted Vision and Color Card, the Moon cards explaining resolution, a spoon, and the foam and sticks. They will be invaluable for explaining things at a star party. The people who do presentations in classrooms or before a star party should have copies of the Multiwavelength Universe Poster and sorting cards as well.

Astronomical Society of the Palm Beaches

Most of the activities are best done outside at night, with telescopes present. A selection of different sizes and types of telescopes (when pointed at the same object) is a concrete reinforcement of some of the concepts presented.

Statesboro Astronomy Club

Practice with club members at your meeting, review the DVD and manual. You can find a lot of these items in your local stores to make duplicates for all your club members, such as the spoon and foam/sticks.

The Darien O'Brien Astronomy Club

Don't view the introductory video in just one sitting. Watch a part of it and then [try out] the activity you just watched. Spend a few nights working through each of the activities—don't skip any of them since each one teaches a valuable concept about the telescope.

Aldrich Astronomical Society

If you want to begin an astronomy education outreach campaign in your community, this is the kit to start with! Teachers see it as relevant and like the many hands-on activities that can engage their students and help break through the many myths

about telescopes, especially magnification and resolution. I like it because it helps answer questions that even some adult beginners have about telescopes in a very user-friendly way that doesn't put off people who never had opportunities to have their questions about telescopes answered correctly. One person I spoke to said that he wished he had the multi-wavelength posters in his classroom as a child because he finally was able to understand at a glance the concept of the electromagnetic spectrum using the one from the toolkit!

Media and Resources



The “Media and Resources” bag includes:

- The ToolKit Manual on a CD
- The Training Video as a DVD

In the bottom of the box:

- Two posters on multi-wavelength astronomy

The “Training Video DVD” should be viewed as soon as you receive the ToolKit. This will provide an introduction to the activities and materials.

Explore the “Manual and Resources CD”:

- For the ToolKit Manual, open the “0ScopeManual.pdf”
- For PowerPoints, go to the folder labeled “**PowerPoints**”. See below for more information.
- For a history of telescope technologies, open the folder, “**Telescopes Ground Up Website**” and click on “index.htm”. See below for more information.

The handouts for the activities can be found in ScopeManual.pdf so you can personalize them with your club information and print out copies to make for your guests and other club members. The manual also includes sources where you can get more materials.

Feel free to make copies of the **DVD and CD** for distribution to other club members or educators. All materials must be provided free or at your cost.

PowerPoints

TelescopeChgUniv.ppt, along with the script, TelescopeChgUnivScript.doc, is designed for use with your audiences. This PowerPoint is on major discoveries made with telescopes and their technologies that changed the way we understand our universe.

Two support PowerPoints, **MoonMagnify.ppt** and **NotLikePhotos.ppt**, that include a number of the cards in PowerPoint format for presentation to larger audiences.

These are referenced under each activity:

- Moon Magnify.ppt can be used with “Can you see the flag on the Moon?” activities.
- NotLikePhotos.ppt can be used with “Why doesn’t it look like the photos?” activities.

Telescopes From the Ground Up

For a history of telescope technologies, open the folder, “**Telescopes Ground Up Website**” and click on “index.htm”. This website was reproduced from: <http://amazing-space.stsci.edu/resources/explorations/groundup/>. You do not need a connection to the Internet to run the version on the CD

This is an in-depth primer on the history of telescope technologies. With interactive diagrams and historical photos, the material is presented in a logical and easily understood manner. The material is appropriate for junior high school to adults. It can serve as background information for your club members.

How Far Can You See?

Ever had that question at the telescope? Dr. Phil Plait, author of “Bad Astronomy” and Sky Publishing have given permission to use this article from the September-October 2004 issue of Night Sky magazine as a resource for this ToolKit.

“How Far Can You See?” by Phil Plait is from Night Sky, September-October 2004.
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This article is on the Media & Resources CD and is named “**1HowFarCanYouSee.pdf**”.

MicroObservatory

Resource from NASA for educators that have no telescopes. Information can be found on the Media & Resources CD in the file, “**2MicroObservatory.pdf**”.

Making the Photon Connection

Making the Photon Connection by James Mullaney. This is an article about the importance of directly experiencing the night sky.

From Sky & Telescope, June 1994. (c) 1994 Sky Publishing Corp. Reproduced with permission of the publisher.

This article is on the Media & Resources CD and is named “**3PhotonConnection.pdf**”.

Materials for Media & Resources

1. **Copies of the CD and DVD** can be made at your local photo center or other media duplication service.
2. **Posters** can be requested from:
 - a. The Electromagnetic Spectrum (the one from NASA with explanations on the back): Poster can be requested from the Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218 or through email: Origins@stsci.edu.
 - b. The Multiwavelength Universe:
http://coolcosmos.ipac.caltech.edu/resources/paper_products/index.html
3. Another poster, “The Electromagnetic Spectrum”, (not included in the ToolKit) can be requested from: http://www.tufts.edu/as/wright_center/svl/posters/posts.html

Night Sky Network Log Event Form

Starred fields are required.

*Name of Event:	
*Submitted By (Person):	
*Club:	
*Name of Primary Presenter/Organizer:	
Presenter's Profession:	

*Event Type: (Check ONE)	
<input type="checkbox"/> Star Party (Astronomy Night):School/Public/Other Group	<input type="checkbox"/> Girl Scout Event/Meeting
<input type="checkbox"/> Star Party for club members	<input type="checkbox"/> Other Youth Group Event/Meeting
<input type="checkbox"/> Classroom Presentation	<input type="checkbox"/> Other organization's mtng/convention/conference
<input type="checkbox"/> Club Meeting	<input type="checkbox"/> Club newsletter article
<input type="checkbox"/> Astronomy Convention/Conference	<input type="checkbox"/> Newspaper/magazine article
<input type="checkbox"/> Family/Friends Event	<input type="checkbox"/> Television/radio show
<input type="checkbox"/> Other (please specify):	

Name of Group the Event was for:	
* Event Date:	
* Length of Event:	(specify # of mins,hrs, or days - or approx # of words if an article):
* Event Location:	*City: _____ *State: _____ Zip: _____
*Facility Type (Check ONE):	
<input type="checkbox"/> K-12 School	<input type="checkbox"/> Community/Gov't Facility (e.g. Library, Park, Sidewalk)
<input type="checkbox"/> College/University	<input type="checkbox"/> Private Facility (e.g. hotel, private home)
<input type="checkbox"/> Museum/planetarium/observatory	<input type="checkbox"/> Media (newspaper, newsletter, magazine, TV)
<input type="checkbox"/> Other (please specify):	
* Number of your club members participating as presenters: <input type="text"/>	

(Continue to Page 2)

*Toolkit Activities Used	<input type="checkbox"/> Telescope Treasure Hunt
PlanetQuest (Check all that apply)	<input type="checkbox"/> Where are the Distant Worlds (Star maps) <input type="checkbox"/> How do we find planets around other stars? <input type="checkbox"/> Why do we Put Telescopes in Space? <input type="checkbox"/> Used other ToolKit materials
Our Galaxy, Our Universe (Check all that apply)	<input type="checkbox"/> Our Place in Our Galaxy <input type="checkbox"/> A Universe of Galaxies <input type="checkbox"/> Telescopes as Time Machines <input type="checkbox"/> Hubble Video Collection DVD <input type="checkbox"/> Used other ToolKit materials
Black Hole Survival (Check all that apply)	<input type="checkbox"/> Black Hole Explorer Board Game <input type="checkbox"/> Gravity & the Fabric of Space <input type="checkbox"/> Where are the Black Holes? <input type="checkbox"/> Used other ToolKit materials
Telescopes: Eyes on the Universe (Check all that apply)	<input type="checkbox"/> Ready to Observe? (Averted Vision/Color, FOV Card, Spoon) <input type="checkbox"/> What Power is your Telescope? (Foam & Sticks, NASA Apertures) <input type="checkbox"/> Why Doesn't It Look Like the Photos? (Exposure Time / Representational Color) <input type="checkbox"/> Can you see the Flag on the Moon? <input type="checkbox"/> Used other ToolKit materials
Other NSN Resources (Check all that apply)	<input type="checkbox"/> NSN Telecon(s) <input type="checkbox"/> NSN Discussion Board Outreach Ideas <input type="checkbox"/> Other NSN Resources
NONE	<input type="checkbox"/> No NSN Outreach ToolKits or Resources Used PLEASE NOTE: This event will be informational only. This event didn't include the use of NSN Resources, so it will NOT apply to: <ul style="list-style-type: none"> • This club's annual five-NSN-events-a-year membership requirement. • Quarterly and annual prize drawings • The Event Counter • This club's total on the "Stars in the Night Sky Network" listing

(Continue to Page 3)

<input type="text"/>	*Total Number of Visitors or Audience Members (if unknown, please estimate)
----------------------	--

Demographics of audience members are requested by government agencies. If exact numbers are unknown, please try to estimate. Otherwise, leave the space blank.

Estimated #	How many visitors or audience members were...		
<input type="text"/>	Minority?	<input type="text"/>	Adults?
<input type="text"/>	Female?	<input type="text"/>	Teens?
		<input type="text"/>	Children?

IF A SCHOOL EVENT:

Estimated #	How many audience members were...		
<input type="text"/>	Non-teacher adults?		
<input type="text"/>	K-8th Grade Teachers?	<input type="text"/>	K-8th Grade Students?
<input type="text"/>	High School Teachers?	<input type="text"/>	High School Students?
<input type="text"/>	Community College Instructors?	<input type="text"/>	Community College Students?
<input type="text"/>	Other College or University Instructors?	<input type="text"/>	Other College or University Students?

<p>What materials (and how many) did you hand out at the event, if any?</p>
--

<p>Provide a few comments or interesting anecdotes about the event:</p>
--

- **PHOTOS:** If you wish to include electronic photos, you will need to log your event online.
- **Please use this form as a reference to log your event online on the Night Sky Network:**
<http://nightsky.jpl.nasa.gov>
- **OR send the form to your Night Sky Network Club Coordinator**
- **OR mail this form to:**
 Night Sky Network
 Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112
- **OR FAX this form to:** 415-337-5205



Ready to Observe?

What's this activity about?

Big Question: How can we prepare our visitors to understand and enhance their experience at the telescope?

Big Activity: Using a variety of simple props, help the visitor at the scope understand why they see what they see.

Participants: Adults, teens, families with children 5 years and up
If a school/youth group, 2nd grade and higher
From one person to fifteen participants

Duration: **Setup: 1 minute**

Presentations:

- **Why don't I see any color?** 30 seconds
- **Averted Vision** 1 – 3 minutes
- **Field of View Card:** 1 – 10 minutes
- **Why is the image upside down?** 1 – 3 minutes

Topics Covered:

This set of activities helps answer common questions we get at the telescope and provides tools to help your visitors understand what to expect and how to enhance their experience:

- Why don't I see any color?
- How to explain "averted vision"
- Where are you looking?
- How much of the sky are we seeing in the scope?
- Why is the image upside down?

Where can I use this activity?

ACTIVITY	Star Party	Pre-Star Party - Outdoors	Pre-Star Party - Indoors	Girl Scouts / Youth Group Meeting	Classroom			Club Meeting	Gen Public Presentation (Seated)	Gen Public Presentation (Interactive)
					K-4	5-8	9-12			
Why don't I see any color?	√		√	√	√	√	√			
Averted Vision	√	√	√				√			
Field of View (FOV) Card	√	√	√	√	√	√	√		√	
Why is the image upside down?	√	√	√	√	√	√	√		√	

Helpful Hints

1. You might want to make several copies of the Averted Vision & Color Squares card for your club members. Give each member one card and the Field of View card. Punch a hole in the corner and clip them together with a ring or paper clip. Each member operating a telescope would then have a “reference ring” to answer common questions at the scope. Additional cards the member finds useful could be added to the ring.
2. **On the Field of View (FOV) card**, the smallest holes have been made just a hint too large for easier visibility. Note that the instructions say to hold the card “at arm’s length”. There is certainly variation in arm length, but this only makes a slight difference in how much sky can be viewed. The “Backyard Telescope” hole covers about 1/2 of a degree of sky at a distance of about 25 inches from the eye, an average field of view at 70X – 100X magnification in backyard telescopes. Your field of view may vary.
3. **Loose sticks?** If the sticks in the foam get loose after several uses, you can either a) glue them into the holes by wiping the end of each stick over a glue stick or b) move each stick just to the right or left and make a new hole. The second option will only work for 3 or 4 relocations of the stick before you’ll need a new piece of foam.

Background Information

1. Moon Illusion:

http://science.nasa.gov/headlines/y2005/20jun_moonillusion.htm?list227097
<http://www.lhup.edu/%7Edsimanek/3d/moonillu.htm>

2. Eye Physiology: For a nice diagram and discussion on the structure of the eye:

<http://www.biologymad.com/NervousSystem/eyenotes.htm>

3. The following excerpt from the essay "Eye and How it Works..." is reprinted here with permission from Dr. R. A. Greiner "Doc G"

<http://www.mailbag.com/users/ragreiner/>

For the full original article, go to: <http://www.mailbag.com/users/ragreiner/eyeperception.html>

Eye and How It Works when Viewing Faint Astronomical Objects

The eye has an amazing ability to see detail and perceive contrast in both very bright and very dim objects.

Dark Adaptation

The physiology of dark adaptation is complex. The phenomenon of adaptation is highly dependent upon the individual viewer. So, as with all biological effects, only average behavior can be specified. In its simplest form, it is a fact that a viewer's ability to perceive light changes and gets better if the eye is allowed to remain in the dark for some time. This is a chemical effect in the retina of the eye. (Too complex to describe here) Never-the-less everyone experiences this effect. Typically the change in sensitivity is from 2 to 6 magnitudes after 20 to 30 minutes of darkness. It may vary greatly from person to person for reasons related to physical condition of the eye. Typical variations for persons with otherwise normal sight are about 2 magnitudes.

These numbers mean that the sensitivity of the eye may increase after 30 minutes in the dark by as much as 250 times (6 magnitudes). That is a large change and improvement in perceiving dim objects. Brief exposure to bright lights wipes out this improvement almost immediately. Thus viewers should shield their eyes from any light while viewing and especially from very actinic light. Dim red light is the least damaging but even that causes considerable decrease in acuity. Adaptation also depends on the size of a spot of light shown on the retina in a complex way. The best advice is to severely limit exposure of the retina to any light at all so as to retain maximum brightness acuity. An eye patch over the viewing eye is not inappropriate.

These numbers and variations from person to person show why some viewers claim to see Mag 8 stars regularly while other have trouble seeing Mag 4 stars under similar conditions. People's brightness acuity simply varies by a great deal and may depend significantly on the

use of tobacco, alcohol and other chemicals. On a broad average, most persons can see Mag 6 stars on a clear dark night.

The Structure of the Retina of the Eye

The structure of eye is complex, here are outlined only a few factors that directly affect astronomical viewing. The very center of viewing, that is, the point in space that attracts our direct attention when we “look at” an object is focused on a region of the eye called the fovea centralis. This portion of the eye, only a few degrees in angular size, is crammed with visual cones. The cones have the ability to see color but are not highly sensitive to brightness. Immediately surrounding the fovea centralis is a large ring of receptors called rods. The rods have little sensitivity to color but are quite sensitive to brightness. They see in black and white (actually gray). There are, of course, some cones mixed in with the rods so color is perceived everywhere on the retina; but only when the excitation is sufficiently bright. The rods are about 4 magnitudes more sensitive to light than the cones.

There is a spot about 15 to 18 degrees to the nasal side of the retina where the optic nerve enters the eye and is attached to the retina. This spot is blind and may be a couple of degrees in diameter. Notice that since the spot is to the nasal side, the blind region on the surface being observed is in the temporal direction because the lens of the eye turns the image upside down and left to right. But it is important to recognize that when viewing objects they should not be viewed in such a way as to place them on the blind spot.

On the other hand, to the temporal side of the retina, especially at 15 to 20 degrees distance, there are an abundance of cones. This makes the region 15 to 20 degrees to the temporal side of the retina very sensitive to brightness. Thus astronomers use what is called “averted” vision. By forcing the eye to concentrate attention just a bit in the temporal direction, the object is moved onto the region of the eye with the greatest brightness sensitivity. As one eye moves the object into the region of greater sensitivity the other eye moves the object into the blind spot. But viewing is generally done with one eye and whichever eye is used, moving the center of attention toward the temporal side does the desired function.

It is also necessary, when using averted vision to hold the object on the sensitive spot for some time to get the full effect of averted vision. A period of 4 to 7 seconds is usually optimal. Thus, it requires concentration and practice to use averted vision techniques successfully. However, it is worth while to practice this technique since the increase in brightness sensitivity is considerable. Dim extended objects will pop into view that are totally invisible when looking directly at them.

It is definitely worth applying the viewing tactics described above since viewers need all the help possible to see faint extended objects with some reasonable detail. Viewing the “faint fuzzies” takes practice but is well worth the effort.

4. The following essay on Averted Vision is reprinted here with permission from Jeff Medkeff, an accomplished amateur astronomer. For the original article go to: <http://jeff.medkeff.com/astro/observing/averted.html>
For more articles: <http://jeff.medkeff.com/astro/observing/>

Averted Vision

Astronomers often employ an observing technique called "averted vision", the art of looking slightly to the side of a faint object being studied. This works because, we are told, there are more rods slightly off the optical axis of our eyes. But there is a great deal more to it than that, and with some understanding of the physiology of the eye, it will be seen that there are right and wrong ways to use averted vision.

It is true that the density of rods peaks well outside the center of vision. Since the rods are the eye's faint light detectors, it stands to reason that this peculiarity of physiology is what makes averted vision work. The density of the rods at a point 20 degrees off the center of vision reaches about 160,000 rod cells per square millimeter. This is a greater density than the peak density of the cones - the eye's bright light and color detectors - on the fovea (the center of vision), where cones only reach about 140,000 cells per square millimeter.

The point of greatest density of the rods does not correspond to the point of greatest sensitivity, however. The area of greatest sensitivity has been shown to vary considerably from observer to observer, but it is never as far as 18 degrees from the center of vision. The reason for this has to do with the manner in which the retinal cells are "wired" to the brain.

In the fovea, each cone is connected to a single ganglion cell, which in turn is hooked up to a nerve fiber that eventually joins the optic nerve. As we move away from the fovea, each ganglion cell starts to service several cones or rods. Eighteen degrees from the fovea, 100 rods might be connected to a single ganglion cell. At some point on this line extending outward from the fovea, the number of rods per ganglion cell is such that the eye operates at peak sensitivity. For most people, this point is somewhere between 8 and 16 degrees from the fovea.

But so far we have only been considering the sensitivity of the eye as a function of an image's angle from the fovea. One might suppose that it makes a difference if we avert our vision to the left or right, up or down, or at some angle. And it does matter. The most effective direction to avert our eyes is that required to place the object on the nasal side of our vision. Simplified, this means if you are a right-eyed observer, you shift your eyes to the right; if a left-eye observer, you shift your gaze to the left. Whichever eye you use, you avert your gaze in that direction.

By using this most efficient portion of the retina, you will experience a gain of some four magnitudes or more over your direct vision! The effect of this is not insignificant. It means the detection or not of many stars and most details in deep sky objects.

It is important not to avert your vision the opposite direction - that is, if right eyed, you should not use averted vision by shifting your gaze to the left. This will place the image on the blind spot, right where the optic nerve connects to the retina. Nothing will be seen in such a circumstance, no matter how bright!

This poses an interesting dilemma for binocular observers and for those who use binocular viewing attachments on their telescopes. Averting one eye to its optimal position puts the image on, or nearly on, the blind spot on the other eye. This is counterproductive; the advantage of the binocular system is its use of two eyes. Inadvertently disabling one eye makes no sense. The solution is simple, and astronomers have been saying it for centuries: look up!

The second most efficient direction to avert your gaze is upward - look in the direction of the top of your head, so that the image is below your center of vision. The area of the retina in use here is somewhat less sensitive than the optimal horizontal location, but only slightly so. Doing this does not put the image in the blind spot of either eye, and considering the gains to be had from binocular vision, this will likely prove as efficient (or more so) under such conditions as using the optimal monocular method.

If you choose to avert your gaze downward, you will find your averted vision slightly less sensitive again. In actuality, the retina is every bit as sensitive here as it is if you avert your vision upward, but it is sensitive over a much smaller area. Thus, it is harder to consistently rest the image on the "sweet spot".

Some observers will notice that their most sensitive areas are slightly to the side and down, or in other ways not exactly as eye physiology would suggest. In my case, I find averting to the right and slightly up (I am right eyed) is best for me. There are large variations in the way our eyes are made up - in fact, our retinas are even more distinctive than our fingerprints. Almost nothing can be said categorically about vision, but we can say what will apply in the majority of cases. It is well known that experienced observers see much more detail, and many fainter objects, than beginners. I believe that this is caused in part by the observer learning about the individual characteristics of his or her eyes over the course of many nights of observations.

Next time you are out with your binoculars or telescope, take some time to explore these different areas of your vision. It might be quite apparent what is the most promising averted vision method for you. And if it happens to be something other than what medical science predicted, don't let that stop you from doing it your way. They are, after all, your eyes, and only you know what you can see with them.


Detailed Activity Descriptions

If doing these activities as a prelude to an observing session, you might want to introduce your presentation like this:

INTRODUCTION

Leader's Role	Participants' Roles (Anticipated)
<p>Key message for your visitors to take home: The view through the scope is not going to look like the photos you see in magazines.</p>	
<p>Materials: Magazines with astrophotos; Multi-wavelength posters.</p>	
<p><u>To Do:</u> Show magazines, slides, or posters of photos of celestial objects.</p> <p><u>To Say:</u> Are you expecting to see this in the telescope?</p> <p>For the most part, no. Looking at the Moon and planets may show this kind of detail, but things outside our Solar System – out in the realm of the stars, nebula, and other galaxies – are very far away and only a little of their light is reaching us.</p> <p>Your eyes work very differently from a camera that would produce photos like these.</p> <p>We'll show you a few things to help you understand why your eyes won't let you see this kind of image and a few techniques you can use to train your eyes to see as much as you can as you directly experience the universe through the telescopes.</p>	<p>Maybe. Yes. Not sure.</p>

Color: Why don't I see any color?

Leader's Role	Participants' Roles (Anticipated)
<p>Key message for your visitors to take home: Eyes can only see black and white in dim light.</p>	
<p>Materials: Card with color squares.</p>	
<p>SET-UP: This must be done outside at night away from lights or in a room darkened to at least the equivalent of late twilight.</p>	
<p><u>Question from visitor at the scope:</u> Why don't I see any color? <u>To Do:</u> Hand the visitor the color card.</p> <div data-bbox="532 583 1071 961" style="border: 1px solid black; padding: 5px; margin: 10px auto; width: fit-content;"> <p style="text-align: center;">Why don't I see any color in the telescope?</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Look at these squares outside at night away from any lighting or in a dark room. What color is each of these squares?</p> <p>What's going on? The color receptors ("cones") in our eyes are not as numerous and not as sensitive as the black and white receptors ("rods"). In dim light, our color receptors don't work very well, but our black and white receptors do — allowing us to see shades of gray, but not color.</p> </div> <p><u>To Say:</u> What color is each of these squares?</p> <p>Most of the pictures you see in magazines are in color so it might be disappointing not to see any color in the telescope. Our eyes cannot detect much color in dim light. So when we look thru the scope, for the most part our eyes only see shades of gray.</p> <p><u>To Do:</u> Shine a dim white light on the card or bring the card to a place with more light.</p> <p><u>To Say:</u> Now what color are they?</p> <p>The color receptors (cones) in our eyes are not as numerous and not as sensitive as the B&W receptors (rods). We need a lot of light for our eye's color receptors to detect any color at all. When we look at dim objects far out in space, there is so little light reaching us that only our B&W receptors can detect the light.</p>	<p>Not sure. They all look gray.</p> <p>Oh, I see now.</p>

Leader's Role	Participants' Roles (Anticipated)
<p>Dark-adapting your eyes and use of red flashlights: You can extend this discussion to helping your visitors understand why we don't use white light at an observing session.</p>	
<p><u>To Say:</u> Have you walked into a dark room or movie theater and find that you can't see anything? How long does it take before you can find your way around? In dim light, our pupils open wider and our eyes' B&W receptors chemically adjust so we can see dim objects and shapes at night. This is nature's way of giving us night vision. It takes up to 30 minutes for our eyes to fully dark-adapt this way.</p> <p>White light, like a full moon or white flashlights, in a way washes away the chemical and makes us blind to dim objects until our eyes once again adjust. That's why we want to use low-energy red flashlights to minimize loss of our night vision so we can more easily see the detail of the universe as revealed in the telescopes.</p>	<p>Yes. A few minutes.</p>

FIELD OF VIEW: Where are you looking? How much of the sky?

Leader's Role	Participants' Roles (Anticipated)
<p>Key message for your visitors to take home: Telescopes can only see a very small area of sky. When you look at photos taken from various scopes, keep this in mind.</p>	
<p>Materials: Field of View Card</p>	
<p><u>Question from visitor at the telescope:</u> Where are you looking? How much of the sky am I looking at in the telescope?</p> <p><u>To Say:</u> How much of the sky do you think we're looking at? Show me with your hands.</p> <p><u>To Do:</u> Hand the Field of View card to your visitor.</p> <p><u>To Say:</u> Hold this card at arm's length, close one eye, and look through this hole at that area of sky (pointing at the "Backyard Telescope" hole). That's how much of the sky you can see in the telescope.</p>	<p>Guesses.</p> <p>Wow! That's small!</p>
<p><u>To Say :</u> The rest of the holes represent the field of view of various space-based and ground-based telescopes. Let's look at that same area of sky through each hole. How much of the sky can the Hubble Space Telescope see compared to this telescope?</p> <p>When you see a photo taken with the Hubble or one of these other telescopes, that is the amount of sky they were looking at when the telescope took the picture.</p> <p>So if the object covers more of the sky than the telescope's field of view, scientists might take a whole series of pictures and put them together in a mosaic to capture the whole object.</p>	<p>What are the rest of these holes?</p> <p>Wow – I can hardly see anything in there.</p>





<p><i>Additional at-the-telescope activity:</i></p> <p><u>To Do:</u> Using a scope & eyepiece that results in an approximately 1/2 degree field of view, point the telescope toward a bright star anywhere along the plane of the Milky Way for best effect. Really, almost any star will do.</p> <p><u>To Say:</u> Hold this card at arm's length, close one eye, and get that star (pointing) in this hole (indicating the "1/2 degree" hole). How many stars do you see in the hole? That's the field of view of the telescope – the amount of sky you will see when you look thru the scope. Let's look thru the scope at that star now. Now how many stars do you see? How much of the Moon do you think will fit in that hole? Let's try.</p>	<p>Visitor holds card out.</p> <p>Visitor looks thru scope. A lot more! I think the hole is too small.</p>
<p><u>To Say:</u> Where's the Moon? Hold the card out at arm's length. Can you get the Moon in that hole?</p> <p><u>To Do:</u> Move telescope to the Moon.</p> <p><u>To Say:</u> Let's look through the telescope. Are you seeing about the same amount of the Moon in the scope as through that hole?</p>	<p>Visitor find Moon.</p> <p>Yes! Weird.</p> <p>Yeah!</p>
<p><i>Presentation Tip #1:</i></p> <p>Visitors may notice that when they look through the Field of View card, a bright star seems to fill up quite a bit of the hole, but when they look through the scope, the same star appears to take up a much smaller area. Many people believe that telescopes make the stars look bigger. They may be surprised to see that the stars look smaller!</p> <p>The stars are much too small for us to discern any size of the star. The best most backyard telescopes can resolve is one arcsecond of sky. For the most part, stars cover less than 1/1000th of an arcsec of sky! Stars are bright enough for us to see, but much too small for us to resolve. Telescopes have much better resolution than our eye does, so the image is not as smeared out in the scope as in our eye.</p> <p>You can choose a distant city light (if you have such a view available) and show the same effect – look at it through the FOV card then look at it through the scope and compare how much of the field of view it appears to take up in both cases. See the Background Information under the "Can You See the Flag on the Moon?" section for more details.</p>	
<p><i>Presentation Tip #2:</i></p> <p>It is likely that some visitors may not believe you when you use the card to show them how small an area of sky you are looking at in the telescope. You may have to prove it to them by using the card on the Moon or on a terrestrial object – like a distant house or a streetlight, then looking at the same area through the scope. They will see that the area they are viewing is approximately the same size.</p>	

Leader's Role	Participants' Roles (Anticipated)	
Bonus Activity: Moon Illusion: Question from visitor: Isn't the Moon bigger when it is near the horizon?		
Materials: Field of View Card, time is near full Moon with the Moon near the eastern horizon.		
<p><u>To Do:</u> Moon is near eastern horizon. Hand the Field of View card to your visitor.</p> <p><u>To Say:</u> Does the Moon look big now? Hold this card at arm's length, close one eye and center the Moon in this hole.</p>	<p>Yes. Centers Moon</p>	
<p><u>To Do:</u> Wait 1/2 hour to an hour. Point to the Moon.</p> <p><u>To Say:</u> Does the Moon look smaller now? Center the Moon in this hole now. Is the Moon any smaller? It is an optical illusion that the Moon looks smaller near the horizon.</p>	<p>Yes. No.</p>	
<p><u>Presentation Tip:</u> Refer to "Background Information" section for links to discussion of the Moon Illusion.</p>		
<p><u>Using Field of View Card during the Day:</u> Hold card against the sky or if inside against a light colored wall to see the difference in Field of View of the various telescopes.</p> <p><u>Start out by asking your visitors:</u> How much of the sky do you think you will be seeing when you look through the telescope?</p>		<p>Various answers.</p>
<p>How much of the sky do you think the Hubble looks at one time? How about Chandra – the X-Ray Telescope out in space?</p>		<p>Guesses</p>
<p><u>To Do:</u> Hand the Field of View cards to your visitors.</p> <p><u>To Say:</u> Hold this at arm's length against the sky and close one eye – how much of the sky would you see if you could look through each of these telescopes?</p>	<p>Visitor looks at sky through holes in card.</p>	
<p><u>Presentation Tip:</u> Be prepared to speak briefly about what each type of telescope is for and whether it is out in space or on the ground. The Multiwavelength poster might come in handy for this.</p>		

Leader's Role	Participants' Roles (Anticipated)
Bonus Activity: Telescope Photos	
Materials: Field of View Card, images from your magazines, posters.	
<p><u>To Do:</u> Hand the Field of View card to your visitor. Show photo.</p> <p><u>To Say:</u> When the [Hubble, Chandra, ...] telescope took this photo it was only imaging this much of the sky. How many images would it take to image the whole sky? Yes, over 5 million for Hubble. (assuming a Field of View of 1 sq mm at arm's length of 650 mm: surface of sphere: $4 \cdot \pi \cdot \text{radius}^2$ – with 650 mm as the radius – adjust for different Field of Views) It would take almost 600 years to image the whole sky if each exposure was only one hour long.</p>	<p>Wow A LOT!</p>

Upside Down? Why is it upside down?

Leader's Role	Participants' Roles (Anticipated)	
<p>Key message for your visitors to take home: Many telescopes invert the image. This is an effect of a curved mirror.</p>		
<p>Materials: Spoon, foam with sticks.</p>		
<p>Presentation Tip: The only time you probably get this question is when you are looking at the Moon or at a terrestrial object.</p>		
<p><u>Question from visitor:</u> The Moon doesn't look right. It looks upside down.</p> <p><u>To Do:</u> Hand the visitor the spoon and, if it is too dark to otherwise see their reflection, shine a red light indirectly toward their face.</p> <p><u>To Say:</u> Hold this spoon a couple feet from your face.</p> 		
<p><u>Alternate way, using telescope:</u> 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.</p>		
<p><u>To Say:</u> How do you look?</p> <p>Why is your image upside-down?</p>		<p>Upside-down!</p> <p>Shrugs</p>

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.



“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)
<p>Extending the Activity: The telescope also flips the image right for left. The back of the spoon shows you right side up, but a little elongated.</p>	
<p>Materials: Spoon, foam with sticks.</p>	
<p>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.</p>	
<p><u>Question from visitor:</u> Wait a second – when I raise my hand, the opposite hand is raised in my reflection.</p> <p><u>To Do:</u> Hold foam and sticks horizontally.</p>  <p>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.</p> <p><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."</p> <p><u>To Do:</u> Curve the foam strip.</p>  <p>"NOW where is your hand?"</p>	

Question from visitor:

Hey – look at yourself on the other side of the spoon – I’m right side up!

To Do:

Hand the foam & sticks to the visitor.

To Say:

Can you curve the foam strip to show me how the spoon is curved on that side?

So why are you right side up?



Materials

What materials from the ToolKit do I need?



In the “Ready to Observe?” activity bag:

1. Pack of Field of View (FOV) cards (“How much sky can the telescope see?”)
2. 1 - Color squares and averted vision card
3. 1 - Spoon
4. 2 - foam strips
5. Template for foam strips
6. 10 - skewer sticks
7. 1 – straight pin in a card

In the ToolKit Box:

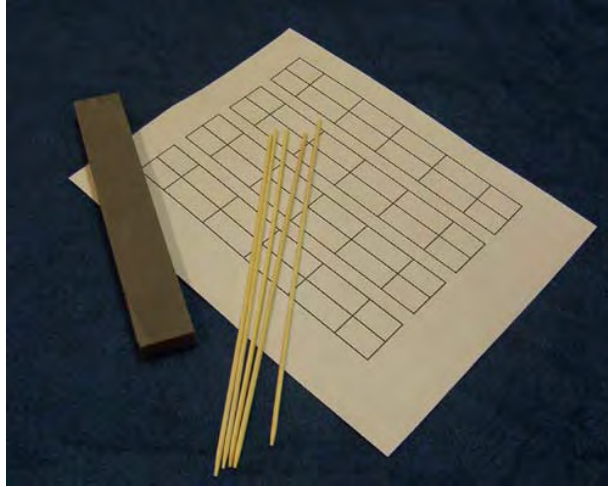
1. 2 - Multi-wavelength Posters

What do I need to prepare?

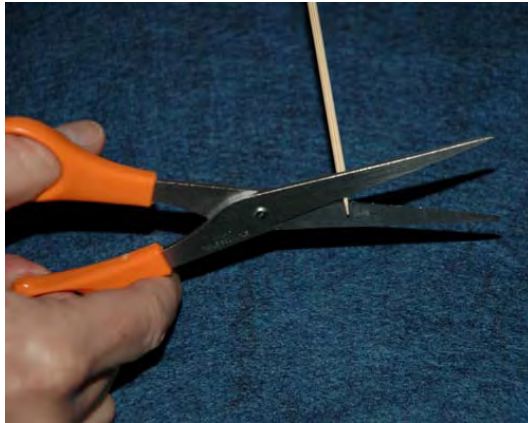
There are enough materials in the ToolKit to make two sets of the foam and sticks.

1. To make the foam and sticks:

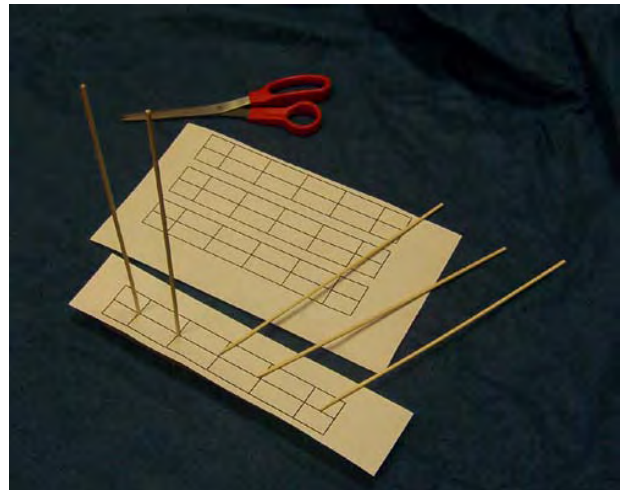
- a) You need the Template sheet, skewer sticks, and foam strips.



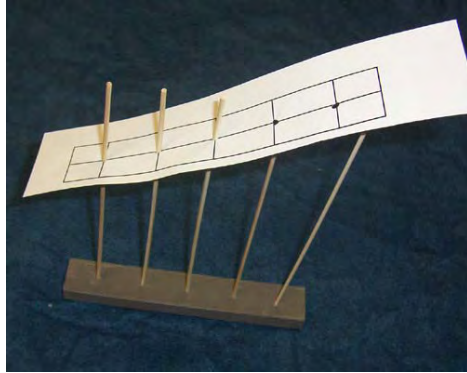
- b) With scissors you supply, trim about 1/4 inch off the sharp end of each skewer stick.



- 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) Assemble the other set of foam and sticks, then put one of the assembled foam strips into the “What Power is your Telescope?” activity bag.



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

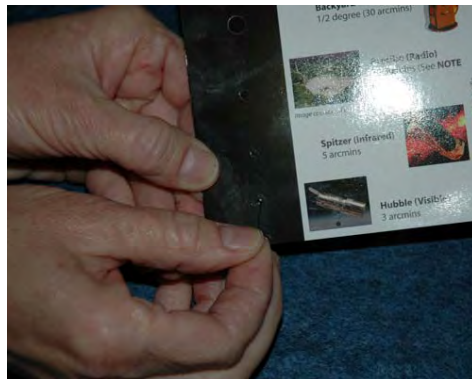
- glue them into the holes by wiping the end of each stick over a glue stick (see photo to the right)



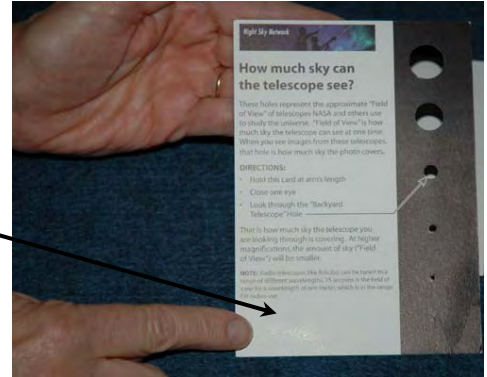
- or move each stick just to the right or left and make a new hole. This option will only work for 3 or 4 relocations of the stick before you'll need a new piece of foam.

2. Field of View Cards

a) Using the included straight pin, poke a pinhole in each of the Field of View cards next to the Hubble telescope image to show the size of the Hubble's field of view. (See photo to the right)



- b) If using Field of View cards as giveaways or gifts, you might want to make stickers with your club information to place on the back of the card in this area.



What must I supply?

- Scissors
- Telescopes
- *Optional:* Additional spoons
- *Optional:* Magazines with astronomy photos

Where do I get additional materials?

1. **Field of View (FOV) cards** (“How much sky can the telescope see?”):
 - a) Masters for the FOV Cards are in this Manual. You may print out more FOV cards on card stock or copy them onto card stock. Punch a hole for the “Backyard telescope” with a regular 1/4” hole punch. Poke a hole for Arecibo using a 16-penny nail. Poke a hole for Spitzer using a small nail or push pin. Poke a hole for the Hubble using a straight pin. For the larger holes, you can use a drill with the correct sized bits (5/8-inch and 1/2-inch), but we recommend just leaving the card with the top two circles intact. Drilling can fray or tear the paper.
 - b) **You may order a pack of 20 Field of View Cards** for \$10 (includes shipping). **To order**, go to the Astronomical Society of the Pacific’s website AstroShop: <http://www.astrosociety.org/astroshop.html>
Click on the “Search” button (top button in left column).
In “Enter Keywords or Item Number to Search”, type in: **NS101**

Then, order the item and complete the order form. When you place your order, you will notice that the system may automatically add \$6.95 for “Shipping”. **If you order nothing else from the AstroShop, no shipping will be charged.** Any “Shipping” charge will be removed before we bill your credit card.

2. Print color / averted vision card from the Manual onto card stock
3. Spoon: your silverware drawer or kitchen supply store.
4. Skewer sticks: grocery store
5. 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.

Averted Vision: Sheet A

“Averted” Vision: How to see more detail in the telescope

Close one eye. Look at the black dot away from your nose.
(In other words, if your right eye is open, look to the dot on the right).

When you look into a telescope eyepiece at a dim object, look to the side away from your nose about as close to the object as the dot is to this photo. The image you are viewing will become brighter and you’ll see more detail.



NGC4414 Image: NASA and The Hubble Heritage Team (STScI/AURA)

Front #1

“Averted” Vision: How to see more detail in the telescope

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NGC4414 Image: NASA and The Hubble Heritage Team (STScI/AURA)

Front #1

Why don't I see any color in the telescope?



Look at these squares outside at night away from any lighting or in a dark room. What color is each of these squares?

What's going on?

The color receptors ("cones") in our eyes are not as numerous and not as sensitive as the black and white receptors ("rods"). In dim light, our color receptors don't work very well, but our black and white receptors do — allowing us to see shades of gray, but not color.

Back #1

Why don't I see any color in the telescope?




Look at these squares outside at night away from any lighting or in a dark room. What color is each of these squares?

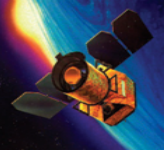
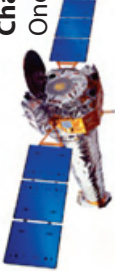




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Field of View: Sheet A

How much sky can the telescope see?




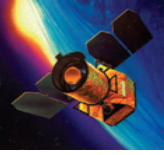
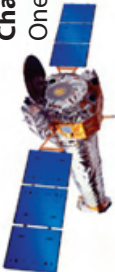


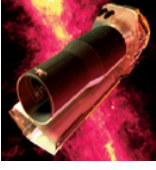

	GALEX (Ultraviolet) 1.2 degrees		Chandra (X-Ray) One degree (60 arcmins)		Backyard Telescope 1/2 degree (30 arcmins)		Arecibo (Radio) 1/4 degree (15 arcmins) (See NOTE on back)		Spitzer (Infrared) 5 arcmins		Hubble (Visible) 3 arcmins
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Front #1

How much sky can the telescope see?



	GALEX (Ultraviolet) 1.2 degrees		Chandra (X-Ray) One degree (60 arcmins)		Backyard Telescope 1/2 degree (30 arcmins)		Arecibo (Radio) 1/4 degree (15 arcmins) (See NOTE on back)		Spitzer (Infrared) 5 arcmins		Hubble (Visible) 3 arcmins
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Front #1



How much sky can the telescope see?

These holes represent the approximate "Field of View" of telescopes NASA and others use to study the universe. "Field of View" is how much sky the telescope can see at one time. When you see images from these telescopes, that hole is how much sky the photo covers.

DIRECTIONS:


- Hold this card at arm's length
- Close one eye
- Look through the "Backyard Telescope" Hole

That is how much sky the telescope you are looking through is covering. At higher magnifications, the amount of sky ("Field of View") may be smaller.

NOTE: Radio telescopes, like Arecibo, can be tuned to a range of different wavelengths. 15 arcmins is the field of view for a wavelength of one meter, which is in the range FM radios use.



Back #1



How much sky can the telescope see?


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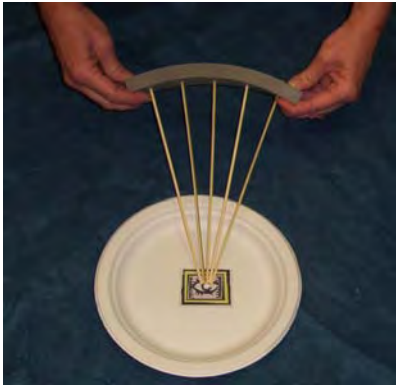
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Back #1

FOAM STRIP TEMPLATES



What Power Is Your Telescope?

What's this activity about?

Big Question: How is the power of telescopes determined?

Big Activity: Using a few simple props, show the basics of how telescopes work.

Participants: Adults, teens, families with children 5 years and up
If a school/youth group, 2nd grade and higher
From one person to twenty participants

Duration: **Setup: 1 - 5 minutes**

Presentation:

- **Introduction: Light spreads out with distance:** 2 minutes
- **How do telescopes work:** 3 – 10 minutes
- **Aperture: How big are telescopes NASA uses?:** 10 – 15 minutes

Topics Covered:

This set of activities provides you with tools to help answer common questions we get at the telescope:

- What power is your telescope?
- How does a telescope work?
- How is your telescope different from Hubble, Chandra, or Keck?

Where can I use this activity?

ACTIVITY	Star Party	Pre-Star Party - Outdoors	Pre-Star Party - Indoors	Girl Scouts / Youth Group Meeting	Classroom			Club Meeting	Gen Public Presentation (Seated)	Gen Public Presentation (Interactive)
					K-4	5-8	9-12			
Light Spreads Out with Distance	√	√	√	√	√	√	√	√	√	
How do telescope work?	√	√	√	√	√	√	√	√	√	
How big are telescopes NASA uses?		√	√	√	√	√	√		√	

Helpful Hints

1. When using the term “aperture”, make sure your visitors understand that this refers to the diameter of the opening in the telescope.
2. Use this activity at a club observing event to help newcomers understand more about their telescope or considerations for buying one!
3. Here are instructions for making a **scale model of the Hubble Space Telescope**: http://hubblesite.org/fun_and_games/hand-held_hubble/

Background Information

1. See the following websites for information on the telescopes on the labels on the string for “How big are telescopes NASA uses?”

- Spitzer (IR): <http://www.spitzer.caltech.edu/spitzer/index.shtml>
- Chandra (X-ray): <http://chandra.harvard.edu/>
- Hubble (Optical): <http://www.stsci.edu/hst/>
- Keck (Optical/IR): <http://www2.keck.hawaii.edu/geninfo/about.php>
- GALEX (UV): <http://www.galex.caltech.edu/>
- Arecibo: <http://www.naic.edu/>

2. The “Power” of a Telescope

People speak of three types of “power” that a telescope has:



- magnifying power,
- resolving power,
- and light-gathering power.

The public most commonly hears about **magnifying** power (e.g., in telescope advertisements that proclaim, “500x power!”). This set of activities helps your visitors understand that although other telescope characteristics, like magnification, are sometimes referred to as the telescope’s “power”, the much more important power of a telescope is its ability to collect a lot of light, which is determined by the aperture (i.e., the diameter of the telescope’s large lens or mirror).

Detailed Activity Descriptions

If doing these activities as a prelude to an observing session, you might want to introduce your presentation like this:

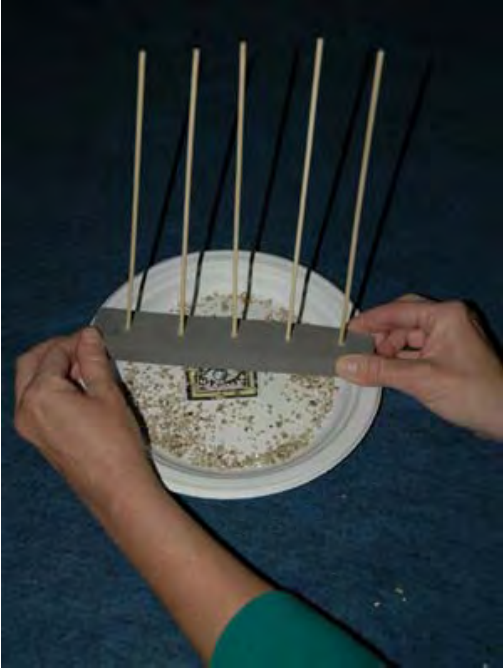

INTRODUCTION – LIGHT SPREADS OUT WITH DISTANCE

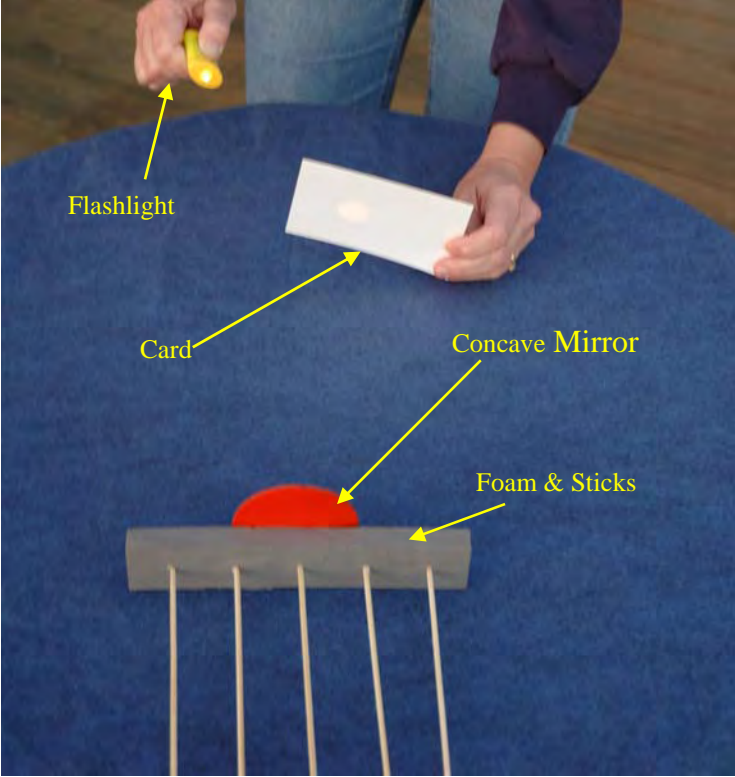
Leader's Role	Participants' Roles (Anticipated)
<p>Key message for your visitors to take home:</p>	
<p>Although other telescope characteristics, like magnification, are sometimes referred to as the telescope's "power", the most important power of a telescope is its ability to collect a lot of light, determined by the aperture (i.e., the diameter of the telescope's large lens or mirror).</p>	
<p>Materials: Eye on paper plate, small flashlight, "photon" container, foam strip w/ sticks</p>	
<p><u>To Say:</u> 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.</p> <p><u>To Do:</u> Tape or place image of eye onto paper plate or to a wall. Hold a small flashlight very near the eye.</p>  <p>Start very close to the eye then move the light away and watch how the light spreads out and dims.</p>  <p>How much light is coming in here (indicating the pupil of the eye). (Refer to a circular plate representing a telescope mirror). "How much light is this one collecting?"</p>	<p>Answers</p> <p>Just that little amount.</p> <p>A lot more.</p>

Leader's Role	Participants' Roles (Anticipated)
<p><u>To Say:</u> 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?</p> <p>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. 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 light is spread out.</p> <p>A galaxy outside of the Milky Way is tremendously far away and its light is spread out 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 light.</p>	<p>Probably not.</p>

HOW DO TELESCOPES WORK?

Leader's Role	Participants' Roles (Anticipated)
<p>Key message for your visitors to take home: Telescopes collect more light and concentrate the light so it will fit into our eye, allowing our brain to detect the object.</p>	
<p>Materials: foam & sticks, eye, plate; concave mirror, "photon" shaker</p>	
<p><u>To Say:</u> This plate represents the size of a mirror in a telescope. Our eye needs at least 500 photons, or packets of light, coming into it every second for our brains to sense that something is there. We'll use these grains represent photons of light from a distant galaxy. We'll sprinkle these photons for one second on this area (indicating the plate).</p>  <p><u>To Do:</u> You or a participant sprinkles vermiculite ("photons") on plate with eye.</p> <p><u>To Say:</u> Will our eye ever detect the light? How many photons are getting into our eye? Is that enough light for our brains to detect it? Is there enough light hitting the telescope mirror (indicating the plate)?</p>	<p>Just a few No. We need 500 photons. Yes!</p>

Leader's Role	Participants' Roles
<p><u>To Do:</u> Hold foam strip on surface of plate - Foam strip represents a section of the telescope mirror.</p>  <p><u>To Say:</u> But how can we get all the light hitting the telescope mirror into our eye? Let's remove a strip of the telescope mirror. The sticks show the light from that galaxy reflecting off the telescope mirror.</p>	<p>Don't know!</p>
<p><u>To Do:</u> Bend foam strip.</p>  <p><u>To Say:</u> A telescope mirror is curved. So when the light comes in, the mirror reflects the light back to a point, like this. Now can we fit all this light into our eye? In essence, this is what telescopes do: concentrate the light to what is called a focal point (or focal plane) and, using a second mirror, redirect that light through the eyepiece and into our eye. That's how we are able to see dim objects, like distant galaxies, using a telescope.</p>	<p>Yes!</p>

Leader's Role	Participants' Roles
<p>To extend the activity: To show actual light path compared to foam and sticks. <i>To Say:</i> Now we're going to demonstrate directly how the curved mirror concentrates the light.</p> <p><i>To Do:</i> Lay the foam and sticks on a table and lean the concave mirror against it. (In the photo below, you are seeing the back of the concave mirror leaning on the foam).</p>  <p>Reflect a light, like a single bulb flashlight, into the concave mirror and direct the reflection onto a light-colored card. The light must be at least a foot (12 inches or 30 cm) from the mirror. The focal length of the mirror provided is between 15 – 20 cm (6 – 8 inches). The distance between the card and the mirror when the light is concentrated to a point is the focal length of the mirror.</p>	

To Say:

Let's watch the light get concentrated.

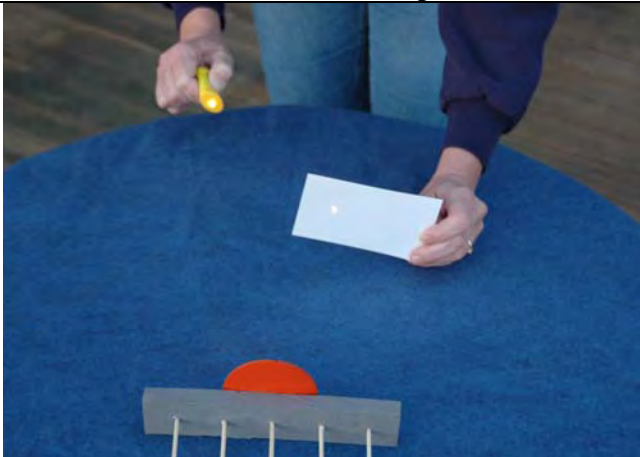
To Do:

Move the card close to the mirror. Then start moving it farther away from your mirror – watch the light circle start large, then concentrate to a point, then get big again – just like the sticks on the curved form.



In front of the focal point.

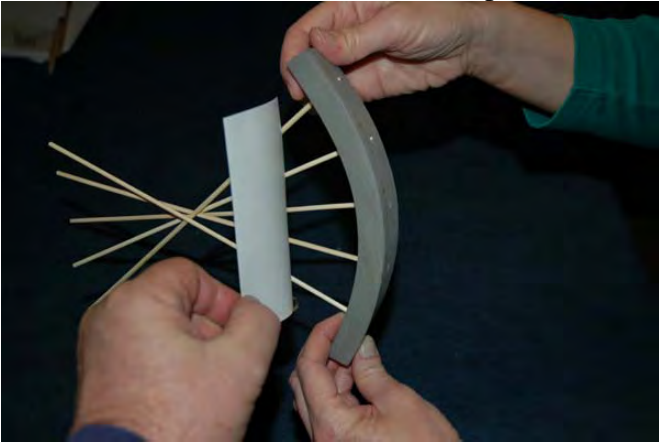
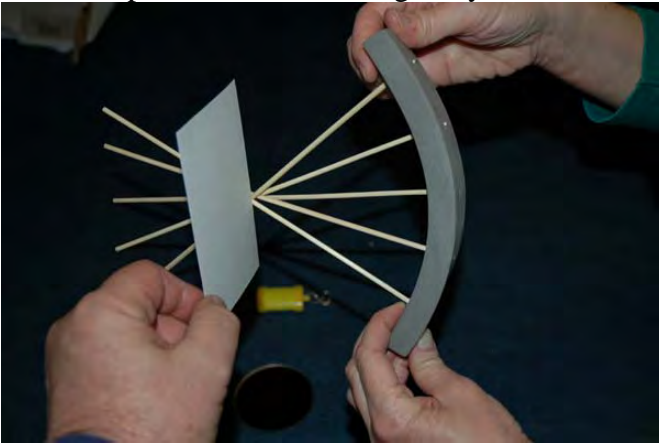
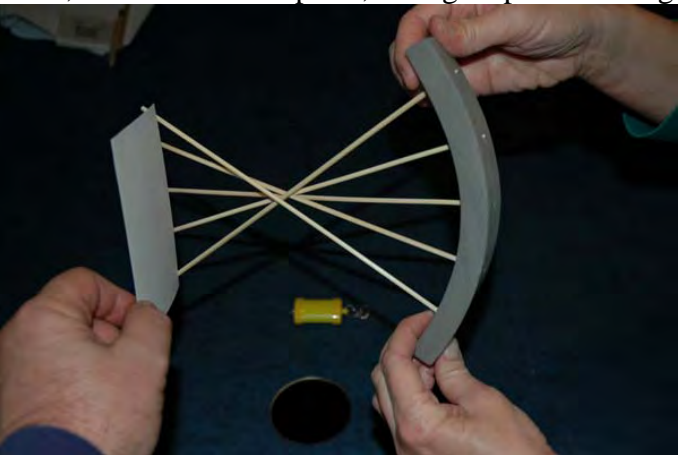
Participants watch or help.



Here's the focal point.



And then the circle of light gets big again in back of the focal point.

Leader's Role	Participants' Roles (Anticipated)
<p data-bbox="235 247 337 279"><i>To Say:</i></p> <p data-bbox="235 283 1019 352">Let's see what's happening with the light using our foam strip model.</p> <p data-bbox="235 357 889 388">Here's what it looks like in front of the focal point,</p>  <p data-bbox="251 829 1068 861">here's the focal point –see how the light rays are concentrated –</p>  <p data-bbox="276 1302 1042 1333">and here, behind the focal point, the light spreads out again.</p> 	<p data-bbox="1107 357 1383 426">Participants watch or help.</p>

To extend the activity:

To show why you need an extremely smooth mirror.

To Do:

Using the foam and sticks, bend the foam so the sticks come to a focal point.

To Say:

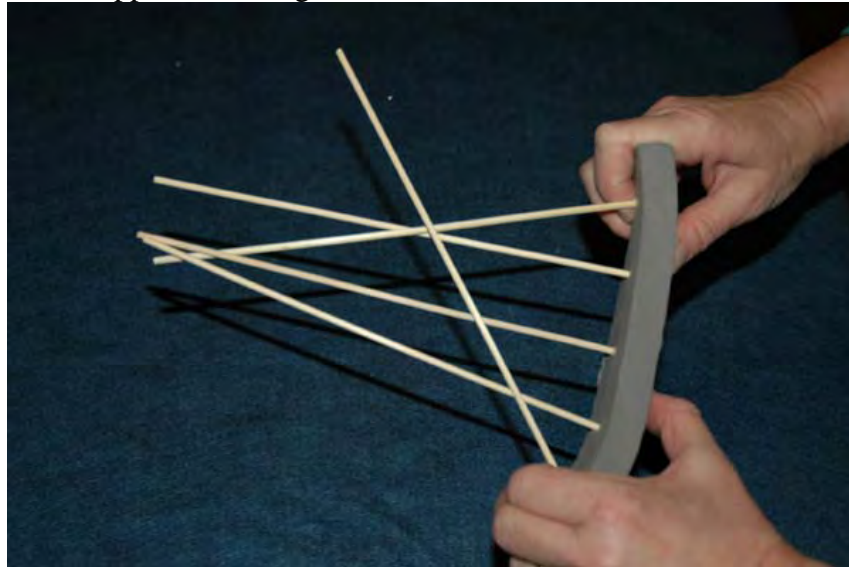
This is how the light comes together to a point with a well-made mirror.

To Do:

Push the foam so there is a small bump in the curved surface.

To Say:

What happens to the light if the mirror is not smooth?



It goes in all directions. You don't get a focal point. It's not concentrating the light properly.

APERTURE – HOW BIG ARE TELESCOPES NASA USES?

Leader's Role	Participants' Roles
<p>Key message for your visitors to take home: The power of a telescope is primarily aperture, not magnification or length. Its power is mostly determined by its ability to collect a lot of light.</p>	
<p>Materials: Aperture string, chalk</p>	
<p><i>To Do:</i> Get four or five participants to stretch out the aperture string to draw the diameters of various kinds of telescopes. You will need a large area, depending on how many of the mirrors you will be drawing. Note the diameters. Options for surfaces to construct mirror diameters:</p> <ul style="list-style-type: none"> • A grass field and use people, or lengths of rope to mark the sizes. • A playground or parking lot and use chalk to mark the sizes • A long hallway or sidewalk and use chalk or markers to mark either side of the telescope mirror. <p>ALTERNATE WAY TO DEMONSTRATE APERTURE SIZES: Cut out circles from a plastic drop cloth (you can purchase this from a painter's supply store) or a large plastic tablecloth (from a party supply store). Lay the circles on the ground, putting the largest one down first. If it is windy, you'll need to use masking tape or rocks to hold down the circles. This is a quick, reusable way to show the apertures.</p>	

To Say:

How big are telescope openings? How big are their light-collecting areas?

Here we have a string that has various markers marking the size of various telescopes. Who wants to be at the center of these telescope openings? And who wants to hold the other end?

Now we need one person at each marker to mark the telescope size. Let's draw circles to represent the sizes of the light-collecting areas.

To Do:

Direct the person at the end of the string to stretch the string straight. Have each person at a telescope label mark the ground with their chalk.

Direct the person at the end of the string to move a few feet, then have the telescope label people make another mark.

Continue until the circles are complete.



To Say:

Let's walk across (or around) each telescope.

Compared to this telescope (indicate an amateur scope), can this one (indicate one of the circles) collect more or less light?

Walk and consider; give answers

Leader's Role	Participants' Roles (Anticipated)
<p>To extend the activity: Compare how many more grains of vermiculite (or sand) – representing photons – the larger telescopes can collect.</p>	
<p>Materials: Aperture string – marked out telescope apertures from the “Apertures” activity. <i>(Optional)</i> You supply: More vermiculite or sand.</p>	
<p>Presentation Tip: Only do this outside on a surface that won't be damaged or cause people to slip on the sand or vermiculite. Unless you have the means to clean up the grains, it must be where it won't matter that the grains are left on the surface, like a parking lot or a grass field.</p>	
<p><u>To Do:</u> Get four or five participants to spread vermiculite (or sand) at the same concentration as the grains on the eye and plate, counting how many teaspoons they can spread over each scope. <u>To Say:</u> If we used one teaspoon to cover the 8” telescope mirror, how many teaspoons do you think it will take to cover this telescope opening (point to one of the circles)? Let's try!</p>	<p>Guesses.</p>
<p>Presentation Tips: If doing this for a classroom, you can also just have the kids calculate how much more surface area each telescope has – using the formula pi times radius squared. Take the radius as shown on each label on the string – make sure they are all in the same units! Square the radius of the telescope aperture and multiply by pi (π or 3.14). For example, if your telescope had an aperture of 10”, its radius is 5”. $5^2 * 3.14 = 25 * 3.14 = 78.5$ square inches. The Hubble is 8 feet or 96” in diameter. Its radius is 48” $48^2 * 3.14 = 7,235$ square inches. Almost 100 times more light-collecting area than the 10” telescope. This would be about 2 cups of vermiculite (or sand).</p>	

Materials

What materials from the ToolKit do I need?



In the “Power” activity bag:

1. Eyes printed on paper – one has a hole where the pupil is – cut these apart.
2. 8” paper plate
3. Small white-light flashlight
4. Sidewalk chalk
5. String
6. Labels marked with telescope radii
7. Concave mirror
8. “Photon” container – container of vermiculite
9. Adhesive tape

From the “Ready to Observe?” activity bag:

- One foam strip and skewer sticks.

What do I need to prepare?

- a) Assemble foam and skewer sticks from the “Ready to Observe?” activity bag and place one of the foam strips in the “What Power is Your Telescope” activity bag.
- b) Affix the telescope labels to the string at the appropriate distances. You’ll need a tape measure to measure out the distances on the string. Here’s how:
 - i) Tie a loop in one end of the string. This is the center of the telescope apertures.
 - ii) Each label is marked with both the aperture and radius for each particular telescope. The radius is the distance you should place the label from the loop. For instance, the Chandra X-Ray telescope has an aperture of 4 feet, so mark the string at half of that or 24 inches and place the label there.



- iii) You can put a single knot on either side of the label to keep it from slipping.
 - iv) To make the label stronger and more moisture resistant, place tape over the label.



- v) Recommended: Wrap the string around a card or tube to prevent tangling.

What must I supply?

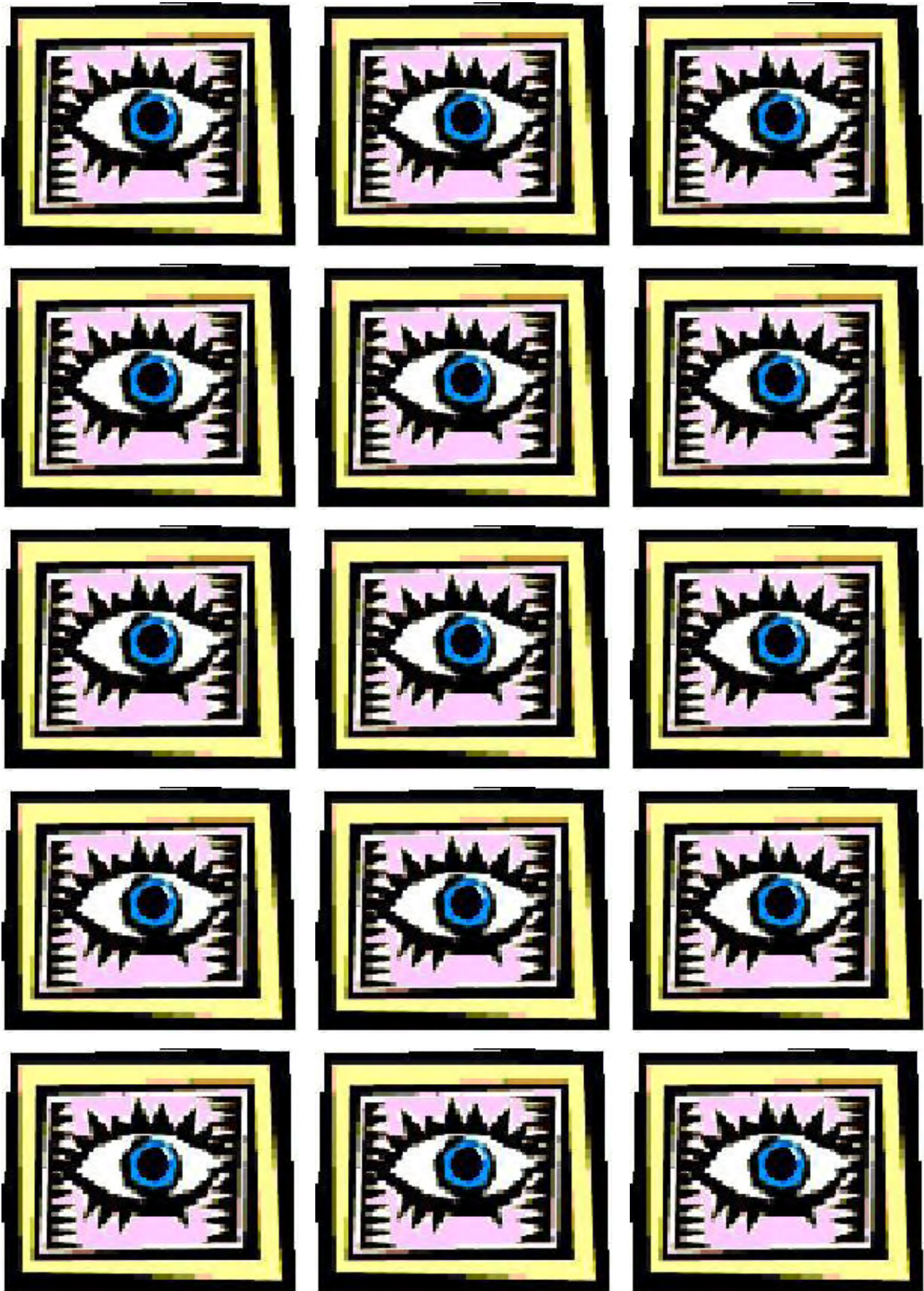
- Tape measure
- Optional: More vermiculite or sand, 2-cup measuring cup
- Optional: Cardboard or paper towel tube to roll string up

If you want to use cutout circles for telescope apertures as suggested under “ALTERNATE WAY TO DEMONSTRATE APERTURE SIZES”, you’ll need to provide:

- Painter’s drop cloth and/or colored plastic tablecloths
- Scissors
- Masking tape or rocks

Where do I get additional materials?

1. Eye: Print from the “Eye Images” page in this Manual. Use a regular 1/4” hole punch to make a hole for the pupil.
2. Paper plate: grocery or variety store
3. Vermiculite (“photons”): nursery or garden supply store.
4. Small Flashlight: Hardware store
5. Skewer sticks: grocery store
6. 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 about 48 strips that are 1-1/4” x 8”. You can use a utility knife to cut the foam.
7. Sand: building or garden supply store.
8. Sidewalk chalk: toy store or variety store
9. String: Hardware or variety store
10. Adhesive tape: Hardware or variety store
11. Concave mirror: Available in 3 sizes from science supply companies like www.schoolmasters.com (Search for “Concave mirror”)





**Optical
Ground
Aperture:**

Backyard Scope



**Optical
Ground
Aperture:**

Backyard Scope



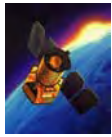
**Optical
Ground
Aperture:**

Backyard Scope



GALEX

**Ultraviolet Space
Telescope
Aperture:
50 cm (20 in)
(10" radius)**



GALEX

**Ultraviolet Space
Telescope
Aperture:
50 cm (20 in)
(10" radius)**



GALEX

**Ultraviolet Space
Telescope
Aperture:
50 cm (20 in)
(10" radius)**



Spitzer

**Infrared Space
Telescope
Aperture:
85 cm (2.8 ft)
(17" radius)**



Spitzer

**Infrared Space
Telescope
Aperture:
85 cm (2.8 ft)
(17" radius)**



Spitzer

**Infrared Space
Telescope
Aperture:
85 cm (2.8 ft)
(17" radius)**



Chandra

**X-Ray Space
Telescope
Aperture:
1.2 m (4 ft)
(24" radius)**



Chandra

**X-Ray Space
Telescope
Aperture:
1.2 m (4 ft)
(24" radius)**



Chandra

**X-Ray Space
Telescope
Aperture:
1.2 m (4 ft)
(24" radius)**



Hubble

**Optical Space
Telescope
Aperture:
2.5 m (8 ft)
(4 ft radius)**



Hubble

**Optical Space
Telescope
Aperture:
2.5 m (8 ft)
(4 ft radius)**



Hubble

**Optical Space
Telescope
Aperture:
2.5 m (8 ft)
(4 ft radius)**



Keck

**Optical / IR
Ground
Aperture:
10 m (33 ft)
(16 ft radius)**



Keck

**Optical / IR
Ground
Aperture:
10 m (33 ft)
(16 ft radius)**



Keck

**Optical / IR
Ground
Aperture:
10 m (33 ft)
(16 ft radius)**



Arecibo

**Radio Ground
Telescope
Aperture:
305 m (1000 ft)
(500 ft radius)**



Arecibo

**Radio Ground
Telescope
Aperture:
305 m (1000 ft)
(500 ft radius)**

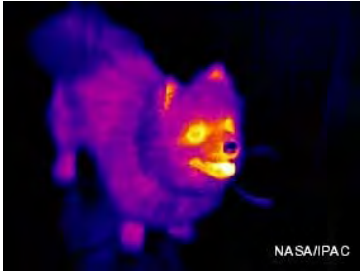


Arecibo

**Radio Ground
Telescope
Aperture:
305 m (1000 ft)
(500 ft radius)**

**These print on
Avery Labels 8160**

1" x 2-5/8"



Why doesn't it look like the photos?

What's this activity about?

Big Question: Why doesn't the view through the telescope look like the photos?

Big Activity: Using posters, demos, and a simple game, help visitors learn about exposure time and energy our eyes can't see.

Participants: Adults, teens, families with children 8 years and up
If a school/youth group, 4th grade and higher
From one person to fifteen participants

Duration: Setup: 2 to 5 minutes

Presentation:

- i. **Exposure time:** Galaxy stencil activity: 3 minutes
- ii. **“Representational” color :**
 1. Rusty, the Infrared Dog and USA images: 5 – 10 minutes
 2. Universe in a Different Light card-sorting game: 10 - 15 minutes

Topics Covered:

This set of activities provides tools to help your visitors understand the two main reasons views through the telescope do not look like photographs:

- Exposure time: why photographs have so much more detail than the view through the telescope.
- Some photographs are showing representational color: Different energies of light and why NASA needs so many different kinds of telescopes to detect that energy.

Where can I use this activity?

ACTIVITY	Star Party	Pre-Star Party - Outdoors	Pre-Star Party - Indoors	Girl Scouts / Youth Group Meeting	Classroom			Club Meeting	Gen Public Presentation (Seated)	Gen Public Presentation (Interactive)
					K-4	5-8	9-12			
Exposure time		√	√	√	√	√	√		√	
Rusty, the Infrared Dog & USA images		√	√	√	√	√	√	√	√	
Universe in a Diff Light Card-Sorting Game		√	√	√		√	√	√	√	

Helpful Hints

1. You might prefer to use “NotLikePhotos.ppt” PowerPoint slides for larger groups instead of the “Rusty, the Infrared Dog” and the USA Images postcards. This PowerPoint is found on the Manual & Resource CD in the “PowerPoints” folder. All the images from the USA cards and Rusty, the Infrared Dog card are in the “NotLikePhotos.ppt” PowerPoint.

Background Information

Representational Color:

http://hubblesite.org/sci.d.tech/behind_the_pictures/meaning_of_color/index.shtml


Multi-wavelength astronomy: refer to a good textbook.


What wavelength ranges are used for:

<http://www.spectrum.ieee.org/publicfeature/aug00/pradf1.html>

Detailed Activity Descriptions

Exposure Time: It just looks like a fuzzy blob!

Leader's Role	Participants
<p>Key message for your visitors to take home: The view through the scope is not going to look like the photographs you see in magazines. Photographs have so much more detail than the view through the telescope because cameras can collect light over time and our eyes constantly refresh the view.</p>	
<p>Materials: Multi-wavelength posters, cup with a stencil of a galaxy attached to the underside of it, laminated cutout of a galaxy, sheet of black paper, and “photon” shaker. You might want to spread out a plastic tablecloth or newspaper to catch stray “photons”.</p>	
<p><u>To Do:</u> Show Multi-wavelength poster with photos of celestial objects.</p> <p><u>To Say:</u> Are you expecting to see this in the telescope? Well, I hope not. Looking at the Moon and planets may show this kind of detail, but things outside our Solar System – out in the realm of the stars, nebula, and other galaxies, - are very far away and only a little of their light is reaching us. And since your eyes work very differently from a camera what you see with your eyes is very different than what photographs like these can show us. We'll let you discover why your eyes won't let you see this kind of image.</p>	<p>Maybe. Yes. Not sure.</p>
<p><u>To Do:</u> Set cup with the galaxy stencil onto a sheet of black paper and hold the galaxy cutout.</p>  <p><u>To Say:</u> Our eyes can't take a time exposure like a camera can – our eyes act like snapshots. The light comes into our eye, passes the signal on to the brain and is gone. Will staring at [your friend's face; that light] make it brighter?</p> <p><u>To Do:</u> Hand visitor the cut out galaxy.</p>	<p>No.</p>

Leader's Role	Participants' Roles (Anticipated)
<p><u>To Say:</u> Here's a galaxy far out in space. Hold it over the telescope opening here (the cup).</p> <p><u>To Do:</u> Hand another visitor the shaker.</p> <p><u>To Say:</u> We'll use these grains to represent photons, packets of light. If we sprinkle the photons for one second, that will represent the amount of light coming from this galaxy and hitting this area in one second – the amount of light our eyes will detect. Go ahead and sprinkle the photons into the telescope.</p>	<p>Visitors participate.</p> <p>Visitor sprinkles "photons" for one second.</p>
<p><u>To Do:</u> Pick up the cup and show the visitor what they will see.</p>  <p><u>To Say:</u> Now that's how much light your eye will pick up from the telescope – you'll see a fuzzy patch of light.</p> <p><u>To Do:</u> Tip the sheet of paper and let the grains fall to one side.</p> <p><u>To Say:</u> Now let's pretend there is a CCD camera – like a digital camera – connected to the telescope that can collect photons over a longer period of time.</p>	

To Do:

Hand another visitor the shaker.

To Say:

Now let's take a time exposure. More time means more photons. Let's sprinkle photons into the telescope for 5 seconds.

To Do:

Pick up the cup and show the visitor the "image" of the galaxy.



To Say:

What makes looking through the telescope special is that you are experiencing the real universe directly, not second-hand in a photograph. The photons coming into your eye are yours alone. You can see exactly where it is in the sky. Looking at a photograph doesn't let you know where it is.

Professional telescopes like NASA uses don't use eyepieces – even if you could go up in space and get to the Hubble telescope, you wouldn't be able to look through it! Those telescopes use various kinds of detectors, and light-collecting devices, like CCD cameras to allow us to understand the universe by analyzing the light collected.


Transition to “Ready to Observe” activities: You may want to go into observing techniques at this point and transition by saying:

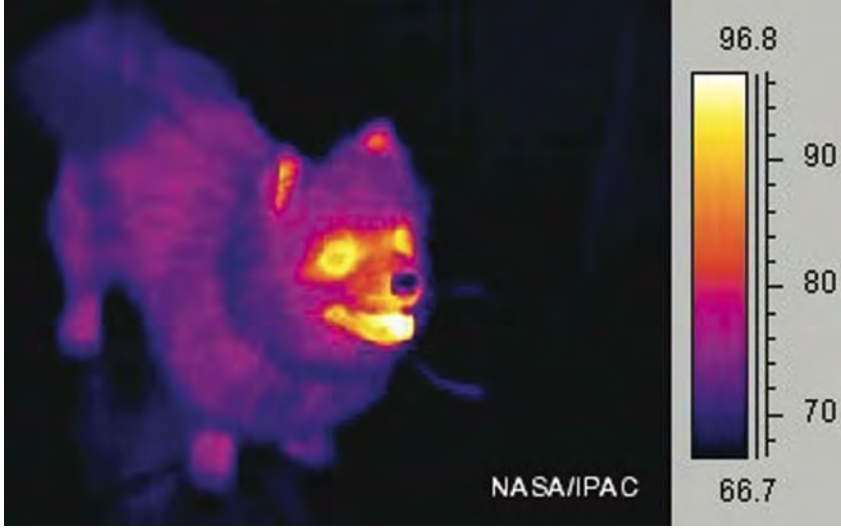
To Say:

But let's see how you can maximize what you *do* see in the telescope.

Visitors participate.

“Representational” Color: INTRODUCTION


Leader’s Role	Participants’ Roles (Anticipated)
<p>Key message for your visitors to take home: There is energy/light our eyes cannot detect. There are many kinds of telescopes to detect different kinds of energy (or light).</p>	
<p>Materials: Rusty card, USA images representing different information. OR PowerPoint presentation: “NotLikePhotos.ppt”, multiwavelength posters</p>	
<p>INTRODUCTION: <u>To Say:</u> Scientists learn a lot from the light we see coming to us from the rest of the universe. But there is more to light than just the colors of light we see in a rainbow. There is more energetic light – UV, X-Ray, Gamma-ray -- and less energetic light – infrared and radio – that our eyes are not sensitive to, that we cannot detect. We need <i>different</i> kinds of detectors.</p> <p>To get a complete picture and understanding of something, we need to look at it in a variety of ways. Let’s see what that means. (To continue, use either “Alternate Introduction 1” or “Alternate Introduction 2”)</p>	
<p>ALTERNATE INTRODUCTION 1: <u>To Do:</u> Show card with photo of Rusty, the dog</p>  <p><u>To Say:</u> This is Rusty. – can you tell by looking at Rusty what parts of Rusty are warm, which cold?</p>	<p>No.</p>

Leader's Role	Participants' Roles (Anticipated)
<p><i>To Do:</i> Show infrared photo of Rusty, the dog.</p>  <p><i>To Say:</i> Does Rusty ever actually look like this? This is an infrared photo that shows us the temperature of Rusty. Which parts of Rusty are the warmest? Which coolest? What color is being used to represent the warmest parts? Could we have used other colors to represent the different temperatures? Right – any color at all!</p> <p>We're using representational color – We are taking energy we can't see and converting it into something our eyes CAN interpret – different colors <u>representing</u> different temperatures.</p>	<p>No!</p> <p>Tongue/mouth/eyes Tail/nose/feet Yellow/white</p> <p>Sure.</p>

Leader's Role	Participants' Roles (Anticipated)
<p><u>To Do:</u> Lay out all four USA images or display them with the PowerPoint.</p>  <p><u>To Say:</u> What are these images of? If you were orbiting the Earth in a spacecraft, which of these images would be most like what you'd see from there? What can we tell from this? Can we see where the mountains are? How about the forests? Desert?</p> <p>What do these other images show us about this area of the Earth? Looking from out in space, by just using our eyes, can we tell where it is warm or cold? (point to temperature map) Can we tell where the rocks are naturally radioactive? (point to Natural Radioactivity map) Where is cell phone coverage best? (point to cell phone map) For those we need special detectors. You can't use just your eyes.</p> <p>These other images are using <i>representational</i> color – taking energy we cannot detect with just our eyes and converting it into something our eyes CAN interpret – different colors representing different information about the USA.</p> <p>The same is true for some of the great astronomy pictures you see. (point to a multiwavelength poster or the back of the cover card for the Universe in a Different Light postcards) The colors are beautiful, but often they are representational color, telling a much richer story to the astronomer who created it. The colors may represent composition or signal strength.</p>	<p>Continental United States.</p> <p>Point to satellite image. Yes. Yes.</p> <p>Temperature, radioactivity</p> <p>No.</p> <p>No. No.</p>

Leader's Role	Participants' Roles (Anticipated)
<p><u>To Do:</u> Show cell phone coverage map.</p> <p><u>To Say:</u> How many of you have used a cell phone? A cell phone is a radio receiver. How do you know where the signal is strong? Can you look around you and see the radio waves coming at you? What do you need to do?</p> <p>What do you suppose the shading on this cell phone coverage map represents?</p> <p>This could once again be using different colors to represent different signal strengths.</p> <p>Would it be OK to use blue instead of green for the strong signal? Of course, as long as you have an explanation of what the colors mean.</p> <p>The same is true for some of the great astronomy pictures you see. The colors are beautiful, but often they are representational color, telling a much richer story to the astronomer who created it. The colors may represent composition or signal strength.</p>	<p>No Look at the bars on the phone.</p> <p>Dark green is strong signal. Lt green weak. White – no service.</p> <p>Sure.</p>

Universe in a Different Light Card-Sorting Game

Leader's Role	Participants' Roles
<p>Key message for your visitors to take home: There is energy/light our eyes cannot detect. There are many kinds of telescopes to detect different kinds of energy (or light).</p>	
<p>Materials: Universe in a Different Light Playing Cards and Postcards</p>	
<p>Presentation Tip: If you have a large group of people, you might want to give one image to each person and then let the crowd group themselves. If this is outdoors and windy and you have only a small group of people, rather than spread out the images on a table, give each person 3 or 4 images.</p>	
<p>SEE "INTRODUCTION" to introduce this activity.</p>	
	<p>Stars, planets</p>
<p><i>To Say:</i> We're standing on the surface of Earth looking out at the universe. What can we see looking through the telescopes we have outside, using our eyes as detectors? We can see the visible light with our eyes, but we need other kinds of detectors to see the other kinds of radiation or energy. NASA and others use special telescopes to detect that energy. These different kinds of energy tell us different information about objects we see in the sky. Like the maps of the USA shown in different energies, these are images of various types of objects you might see in the telescopes tonight – each in different kinds of energy (or light). Each card tells you on the back whether it is visible light energy or another kind of light energy. And what that energy is revealing about the object. The card with the "Visible" light image has the type of object printed on the back (show an example).</p>	


To Do:

Show Postcard with the five galaxy images or select something from the multiwavelength poster.

Let's take a distant galaxy (M51):

- Radio detectors can reveal magnetic fields and cold clouds of gas and dust.
- Infrared detectors find the dust being warmed by nearby stars. Gas and dust combine to make new stars.
- The view our eyes see shows us the combined light of billions of stars.
- Ultraviolet detectors show us where the hot young stars are.
- X-ray detectors reveal massive black holes in the centers of galaxies.

We cannot know any of this by just looking at stars in the galaxy with our eyes (Visible).



To Say:

For example, we have a galaxy here. This one is what we can see with our eyes (point to visible light image). This one is an infrared photo – shows where there is warm dust in the galaxy (or pick any of the images to explain).

To Do:

Shuffle the Universe in a Different Light Playing Cards and spread them out onto a table (or hand them out).

To Say:

Among the cards, there are three different images for each object. And there are [5, 6, 9] objects represented. Which ones go together? Sort them (or yourselves) into groups that represent the same object.

Sort cards into groups.

To Do:

After the groups have been sorted – or they give up – bring out the “Universe in a Different Light” Postcards.

To Say:

Here are the answers – how well did we do? What do these images tell us about the object?

Examines answer cards.

To Do:

Have a discussion, using information on the back of each card master, about what each image shows about the object. (What kind of energy shows where magnetic fields are? What do the ultraviolet images show us?) Use the Multi-wavelength poster for more examples and more information on NASA missions and telescopes making these images.

Presentation Tip:

If you would like to score the group's results:
All 9 correct: Expert observers
5 – 8 correct: Skilled observers
4 or fewer correct: Observers-in-training

Beginners group (5 items – 3 images of each item). These cards have a slight gray border:

- Galaxy (M51), (Visible, UV, IR)
- Open star cluster (M45), (Visible, UV, IR)
- Jupiter, (Visible, Radio, X-Ray)
- Saturn (Visible, Radio, UV)
- Sun (Visible, Radio, UV)

Advanced group (9 items – 3 images of each item):

- Galaxy (M51), (Visible, UV, IR)
- Open star cluster (M45), (Visible, UV, IR)
- Globular cluster (M13), (Visible, UV, IR)
- Planetary Nebula (M27), (Visible, IR, X-ray)
- Star-forming region (M42), (Visible, IR, UV)
- Supernova remnant (Cass-A) (Visible, IR, X-ray)
- Jupiter (Visible, Radio, X-Ray)
- Saturn (Visible, Radio, UV)
- Sun (Visible, Radio, UV)

Materials

What materials from the ToolKit do I need?



In the “Why Doesn’t it Look Like the Photos” activity bag:

1. 3 – galaxy stencils (black)
2. 3 – laminated galaxy cutouts (white)
3. Black construction paper
4. White construction paper
5. 4 – USA images cards (2-sided)
6. Universe in a Different Light (UDL) Postcards
7. Small ring to hold the UDL Postcards together
8. Universe in a Different Light playing cards
9. Rusty, the infrared dog card (2-sided)
10. 1 – “photon” shaker – filled with vermiculite.

In the ToolKit Box:

11. 2 – paper cups
12. Multi-wavelength Poster(s)

In Media & Resources Bag:

13. Optional: “NotLikePhotos.ppt” PowerPoint on Manual & Resources CD

What do I need to prepare?

For “Exposure Time”:

- Cut apart the laminated galaxy cutouts.
- Trace the bottom of the cup over one of the galaxy stencils.



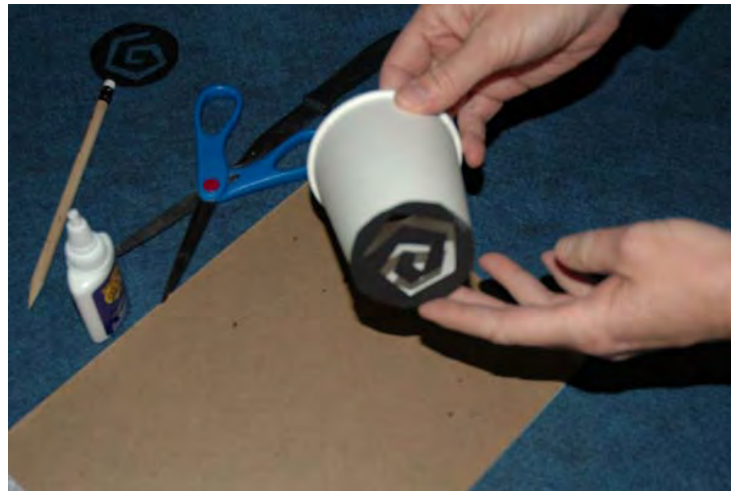
- Cut out the stencil along the line you drew.



- Cut out bottom of paper cup.



- Glue galaxy stencil to the bottom edge of the cup

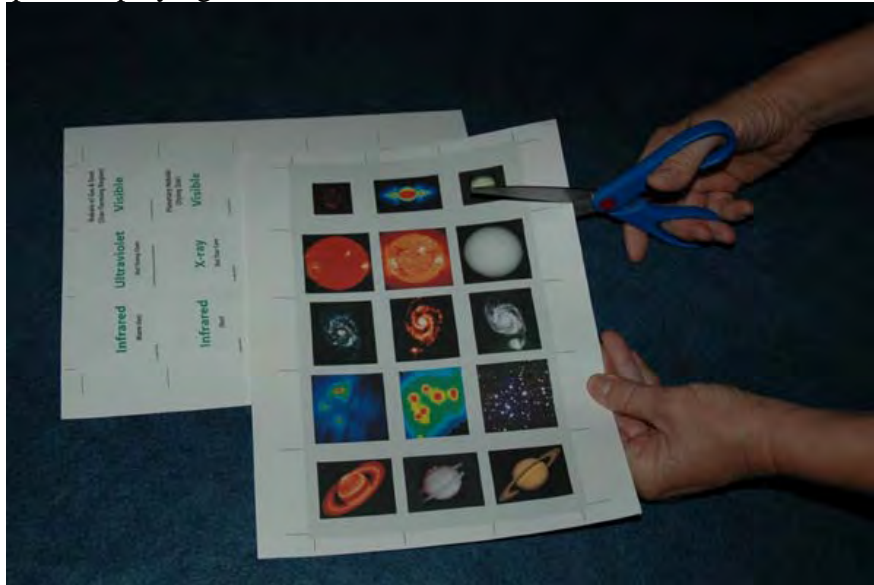


- Place cup on sheet of black construction paper – you might want to spread out newspaper to collect stray “photons”.



For “Universe in a Different Light” card-sorting game:

- Cut apart the playing cards.



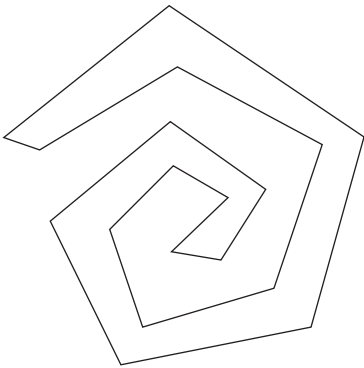
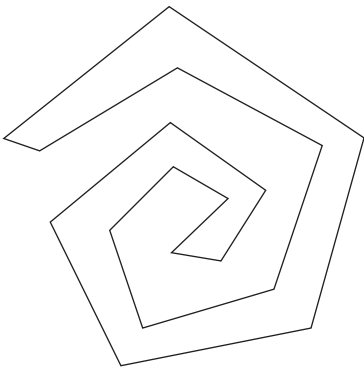
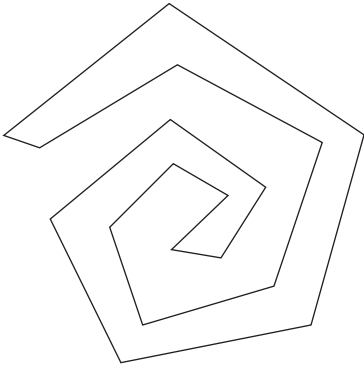
- If desired, punch holes in the corners of the Universe in a Different Light Postcards and use the ring to hold them together.

What must I supply?

- Knife
- White glue
- Scissors

Where do I get additional materials?

1. Cup: any tall paper cup. For use outdoors, you might prefer to use a tin can from which you can remove both the top and the bottom with a can opener.
2. Galaxy stencils & cutouts: cut out from construction paper using “Galaxy Stencils & Cutouts Template” on next page.
3. Vermiculite (“photons”): nursery or garden supply store.
4. Black construction paper: Toy store or variety store
5. USA images cards: print on card stock from the Manual on the Manual & Resources CD.
6. Universe in a Different Light Postcards: print on card stock from the Manual on the Manual & Resources CD.
7. Small ring to hold cards together: office supply store.
8. Universe in a Different Light playing cards: print on card stock from the Manual on the Manual & Resources CD.
9. Rusty, the infrared dog card: print on card stock from the Manual on the Manual & Resources CD.



USA – Satellite Image

What can you see on this satellite image of the USA?



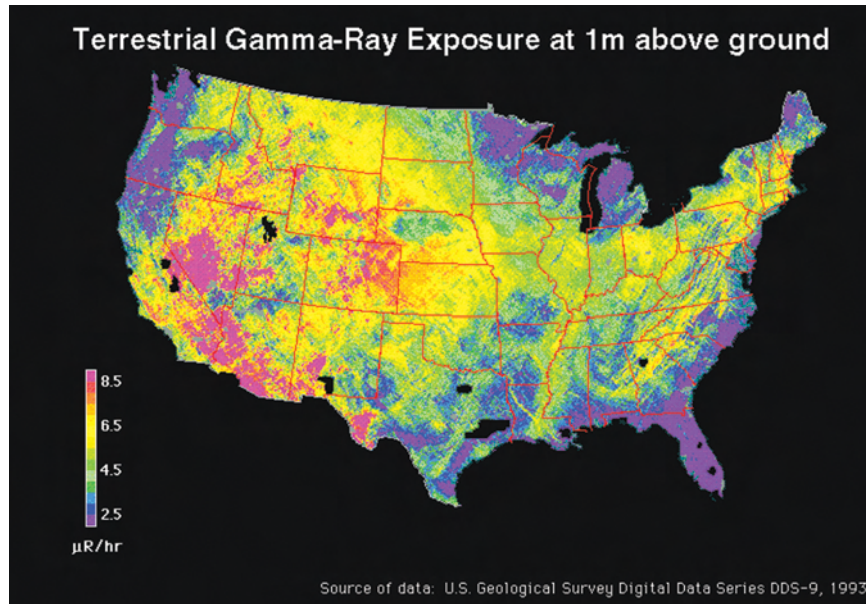
Credit: NASA/GSFC/LaRC/JPL, SRTM/MISR Teams

By just looking, can we tell where it is warm or cold?
Can we tell where the rocks are naturally radioactive?
Where cell phone reception is best?

Front #1

Representational Color – Natural Radioactivity

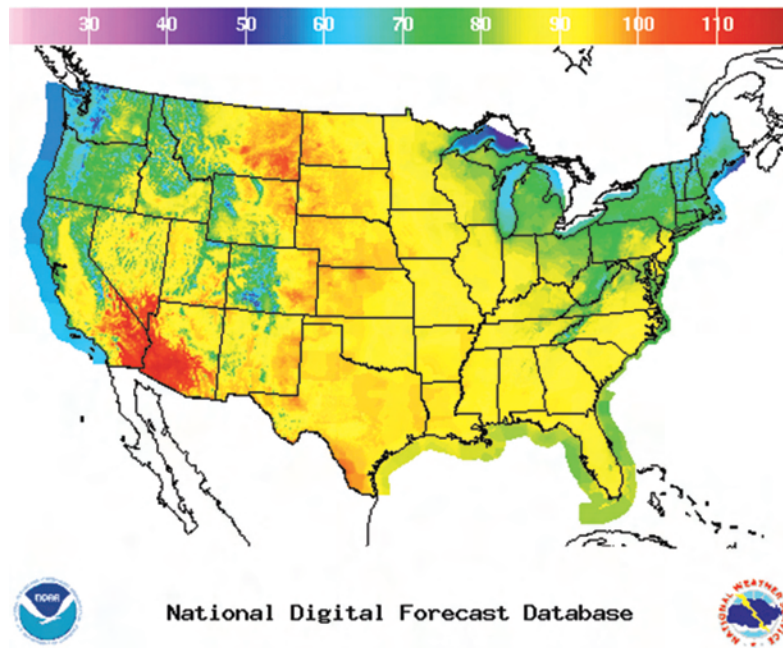
Terrestrial Gamma-Ray Exposure at 1m above ground



Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993

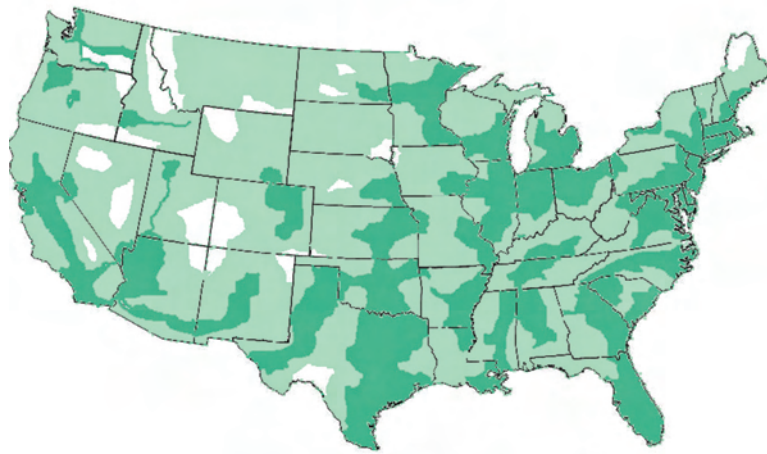
Front #2

Representational Color – Temperature

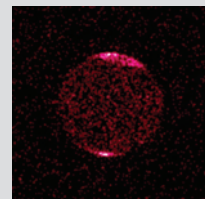
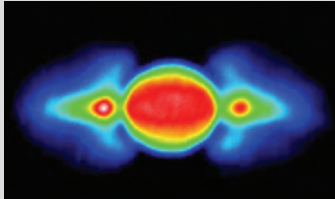
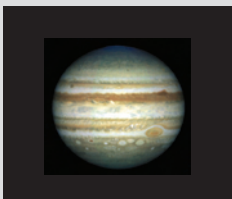
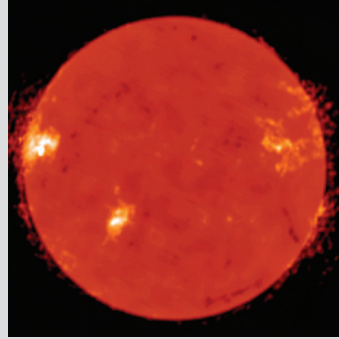
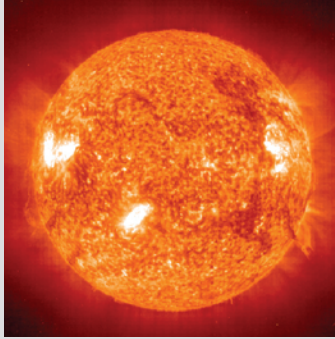
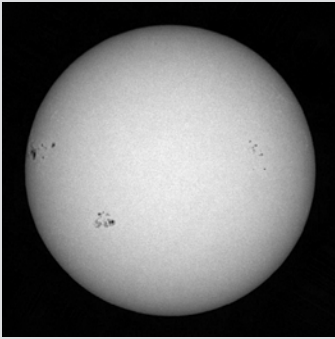
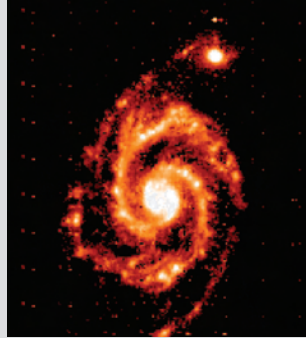
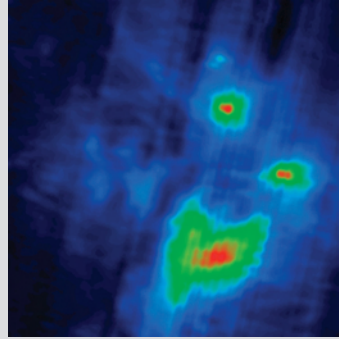
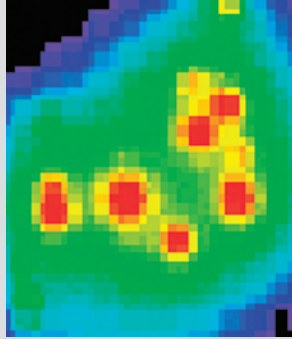
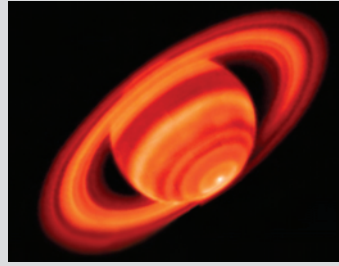
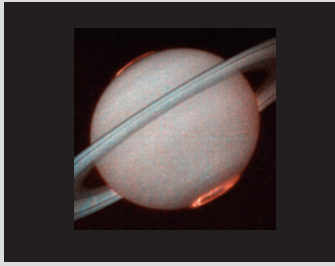


Back #1

Representational Color – Cell Phone Reception (Simulated)



Back #2



Saturn

Infrared

Warmer & Cooler Areas

Credit: W.M. Keck Observatory/NASA/JPL-G. Orton

Ultraviolet

Aurora

Credit: J. Trauger JPL/NASA

Visible

Credit: NASA/JPL/Voyager

Open Star Cluster

Infrared

Warm Dust

Credit: IRAS

Ultraviolet

Hot Young Stars

Credit: Midcourse Space Experiment

Visible

Credit: Alexander Jäger
Interessengemeinschaft Astronomie

Galaxy

Ultraviolet

Hot Young Stars

Credit: GALEX, NASA

Infrared

Warm Dust

Credit: ESA Infrared Space Observatory

Visible

Credit: Digitized Sky Survey

Sun

Radio

Magnetic Fields

Credit: Nobeyama Radio Observatory

Ultraviolet

Hot Gases

Credit: NASA/ESA SOHO

Visible

Credit: Big Bear Solar Observatory

Jupiter

X-ray

Aurora

Credit: NASA/CXC/SWRI/G.R. Gladstone et al.

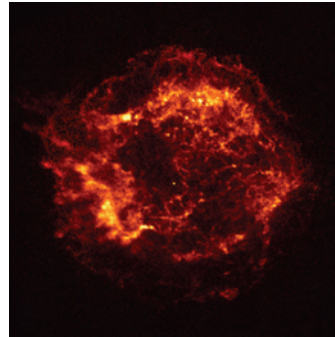
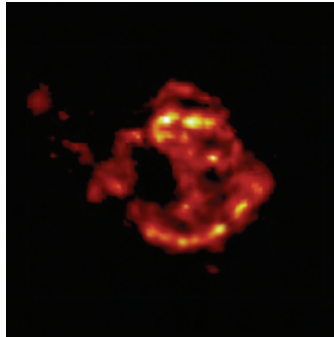
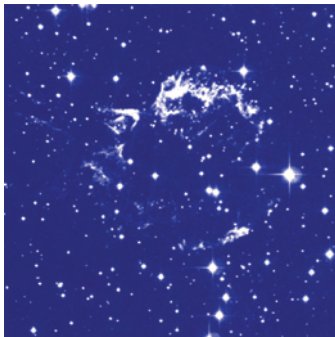
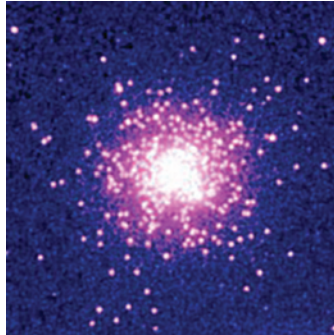
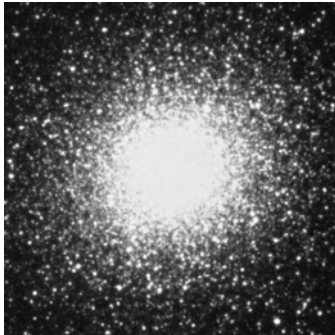
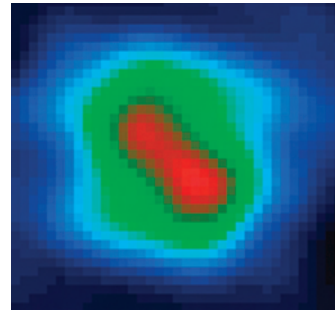
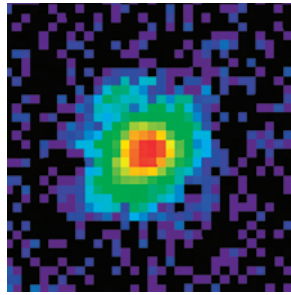
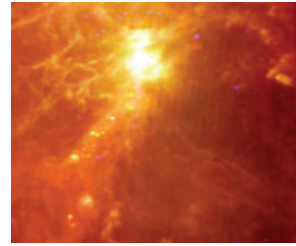
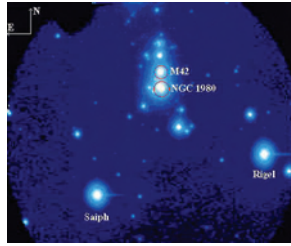
Radio

Magnetic Fields

© Australia Telescope National Facility

Visible

Credit: NASA



**Nebula of Gas & Dust
(Star-Forming Region)**

Infrared

Warm Dust

Credit: IRAS

Ultraviolet

Hot Young Stars

Credit: Midcourse Space Experiment

Visible

Credit: Bill Drelling

**Planetary Nebula
(Dying Star)**

Infrared

Dust

Credit: IRAS

X-ray

Hot Star Core

Credit: ROSAT

Visible

Credit: 2MASS

Globular Star Cluster

Infrared

Dust

Credit: IRAS

Ultraviolet

Hot Star Cores

Credit: FOCA

Visible

Credit: Digitized Sky Survey

Supernova Remnant

X-ray

Hot Gases

Credit: NASA/CXC/SAO/Rutgers/J. Hughes

Infrared

Warm Dust

Credit: Infrared Space Observatory

Visible

Credit: Digitized Sky Survey

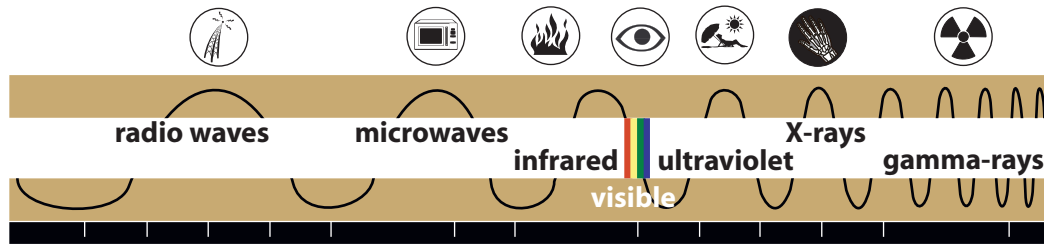
The Universe in a Different Light

There is more to the Universe than meets the eye. By looking in space using detectors for energy invisible to our eyes, we get a more complete story.

Different energies of light reveal many secrets about the lives of stars and galaxies that are otherwise hidden from us.

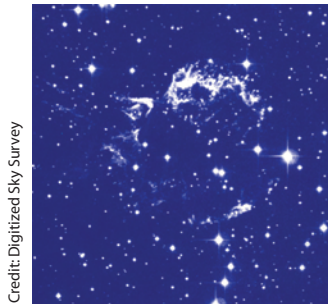
The attached cards contain examples of objects commonly observed with backyard telescopes. The cards contain a typical visible light image and a few images in different energies (or wavelengths) of light.

The explanations on the back of the cards tell what astronomers are discovering by studying objects in energies of light invisible to the eye.

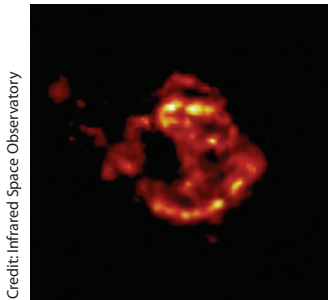


Front #1

Supernova Remnant (Cassiopeia-A)

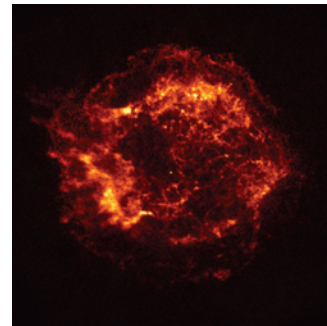


Visible



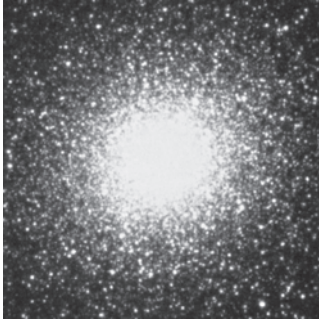
Infrared

X-ray



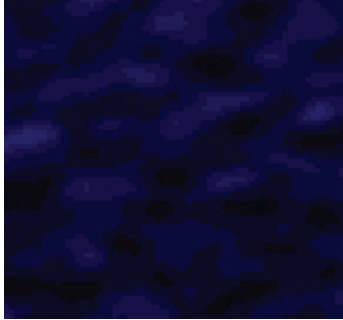
Front #2

Globular Cluster (M13 – Hercules Cluster)



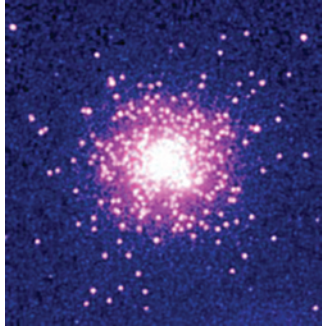
Credit: Digitized Sky Survey

Visible



Credit: IRAS

Ultraviolet

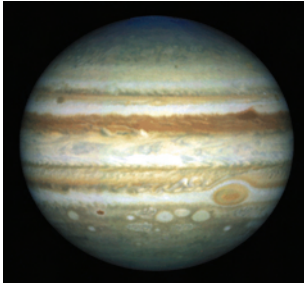


Credit: FOCA

Infrared

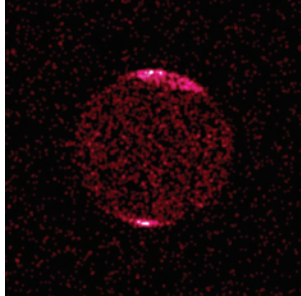
Front #3

Jupiter



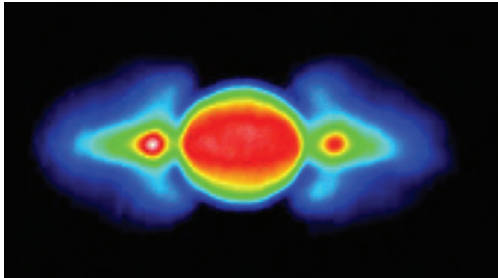
Credit: NASA

Radio



Credit: NASA/CXC/SWRI/G.R. Gladstone et al.

Visible



© Australia Telescope National Facility

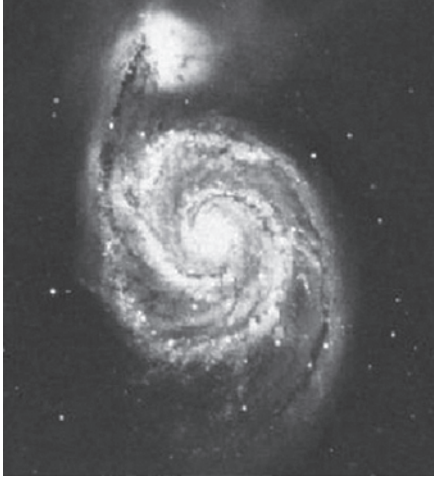
X-ray

Front #4

The Universe in a Different Light: Sheet C

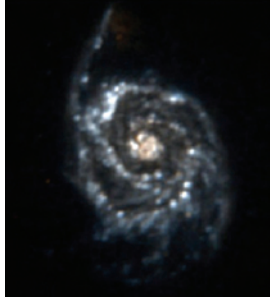
Galaxy (M51)

Visible



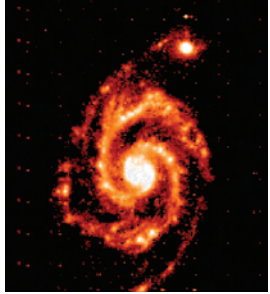
Credit: Digitized Sky Survey

Ultraviolet



Credit: GALEX, NASA

Infrared




Credit: ESA Infrared Space Observatory

Front #5

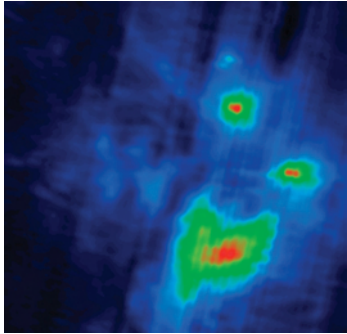
Open Star Cluster (M45 - Pleiades Cluster)

Visible



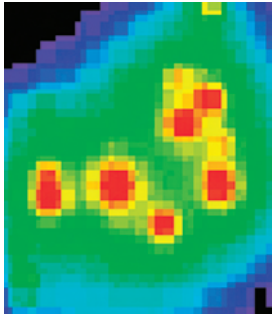
Credit: Alexander Jäger
Interessengemeinschaft Astronomie

Infrared



Credit: IRAS

Ultraviolet



Credit: Midcourse Space Experiment

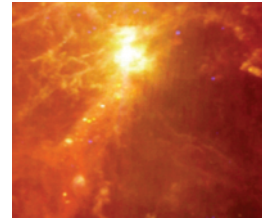
Front #6

Star-Forming Region – Nebula of Dust and Gas (Constellation of Orion & M42)

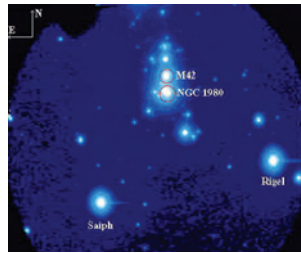


Visible

Ultraviolet



Infrared

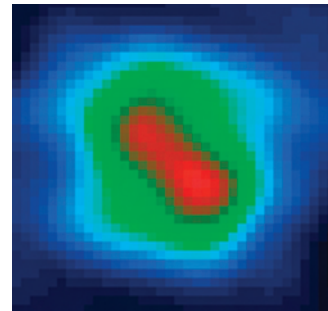


Front #7

Planetary Nebula – A Dying Star (M27 – Dumbbell Nebula)

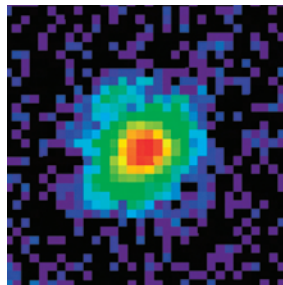


Visible



Infrared


X-ray



Front #8

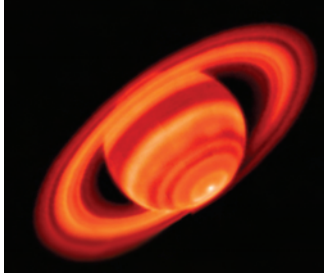
The Universe in a Different Light: Sheet E

Saturn



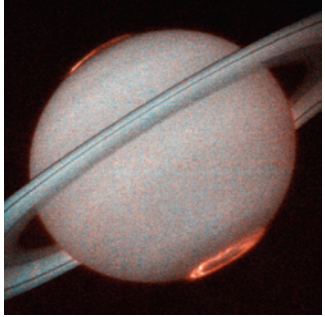
Credit: NASA/JPL/Voyager

Visible



Credit: W.M. Keck Observatory/NASA/JPL-G. Orton

Ultraviolet



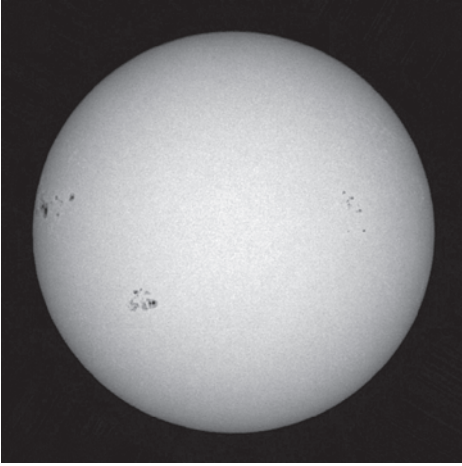
Credit: J. Trauger/JPL/NASA

Infrared

Front #9

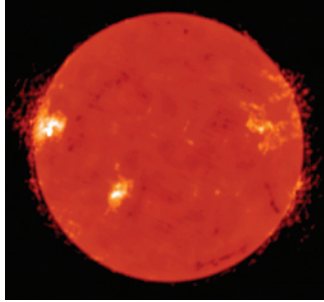
The Sun

Visible



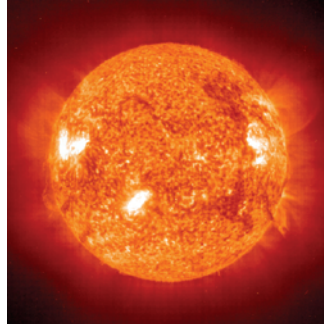
Credits: Big Bear Solar Observatory

Radio



Credits: Nobeyama Radio Observatory

Ultraviolet



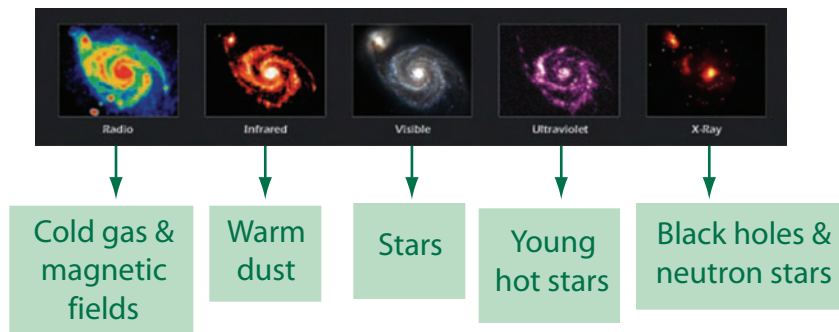
Credits: NASA/ESA SOHO

Front #10

Let's take a distant galaxy (M51):

- Radio detectors can reveal magnetic fields and cold clouds of gas and dust.
- Infrared detectors find the dust being warmed by nearby stars. Gas and dust combine to make new stars.
- The view our eyes see shows us the combined light of billions of stars.
- Ultraviolet detectors show us where the hot young stars are.
- X-ray detectors reveal massive black holes in the centers of galaxies.

We cannot know any of this by just looking at stars in the galaxy with our eyes (Visible).



Back #1

Supernova Remnant (Cassiopeia-A)

This is what remains of the material expelled from a huge star when it died in a supernova explosion.



Visible light: Supernova remnants are often unimpressive in visible light. They barely reveal the expanding shell of gas from the powerful supernova explosion. What can you see in the telescope?



Infrared: Shows the warm dust left over from the explosion. Supernova explosions create the dust of heavy elements, like iron and gold, and spread them out into space. It is this dust that mixes with other dust and gas between the stars and eventually contributes to building new stars and planets, maybe a planet like Earth.



X-ray: The bright regions show where material from the explosion is crashing into the gas and dust of interstellar space, heating it to millions of degrees. These collisions contribute to compressing the gas and dust and after millions of years, forming new stars from the wreckage of these dead stars.

Back #2

Globular Cluster (M13 – Hercules Cluster)



Visible light: When you look through a telescope you see a spherical cluster of thousands of stars tightly bound together by gravity. Do you suppose these stars are young or old?



Infrared: What happened to the cluster of stars? Infrared light is supposed to reveal dust. The view in infrared of this cluster shows us that there is no dust - nothing from which new stars can form. These stars are very old - any dust that was leftover from their formation billions of years ago is long gone. No young stars are in this cluster.



Ultraviolet: If there are no young stars in this cluster, why is the ultraviolet image so bright? These stars are hot, but they are not young. This image shows us which ones are very compact stars nearing the end of their lives: white dwarfs. These stars have lost their outer atmospheres and have used up most or all of their nuclear fuel. All that is left of these is an exposed hot collapsed core.

This is a quiet, serene cluster of old stars all living together for billions of years.

Source: http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m13.html

Back #3

Jupiter



Visible light: As you look at Jupiter through the telescope, note the bands of clouds and its slightly flattened appearance. Watching the features on Jupiter rotate across its face, we can tell this huge planet rotates about once every 10 hours. This fast rotation causes Jupiter to be slightly flattened at the poles.



Radio: Is this Jupiter? Radio energy reveals magnetic fields. In this image, you are able to see that Jupiter has strong magnetic fields - similar to, but much stronger than, the magnetic fields on Earth. Can you see magnetic fields with your eyes? A compass will show you the direction of the magnetic fields on Earth, but we need radio telescopes to reveal the magnetic fields on Jupiter.



X-ray: This image shows us that high-energy particles trapped in Jupiter's magnetic field are accelerated along the lines of force and slam into Jupiter's poles, releasing a lot of energy. Jupiter's strong magnetic fields generate a more energetic aurora (northern and southern lights) than Earth's fields do - so energetic that it is invisible to our eyes.

Back #4

Galaxy (M51)



Visible light: When you look through the telescope at a galaxy, you'll see a fuzzy patch of light. Long exposures using cameras or CCDs will show much more detail, like this image. You are seeing the glow from billions of stars, but what kind of stars are they?



Infrared: In addition to showing stars, infrared reveals dust warmed by stars within the spiral arms. These dusty regions are cool, not nearly as hot as stars, but much warmer than the background of space. Dust and gas are what new stars are made from.



Ultraviolet: Shows star formation concentrated in the spiral arms, since ultraviolet reveals where the massive hot young stars are. What happened to the companion galaxy at the top? Notice that it is not visible in the ultraviolet image, telling us that this region has little or no new star formation taking place.

Back #5

Open Star Cluster (M45 - Pleiades Cluster)



Visible light: You might see a hazy patch in the sky, but the view through a telescope or binoculars reveals many bright stars in a loose group. Do you think these stars are old or young?



Infrared: The view in infrared shows us the warm dust leftover from the recent formation of these stars just a few million years ago. These are *new* stars!



Ultraviolet: The hottest stars can be seen in the ultraviolet image. Can you see how the red spots (which show the highest emissions of ultraviolet light) match the locations of the brightest stars in the visible image?

This is a loose association of new stars, just breaking out of the cocoon of gas and dust where they formed—ready to go out and have lives of their own. These stars will eventually separate from each other—some perhaps with families of planets around them.

Source: http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m45.html

Back #6

Star-Forming Region – Nebula of Dust and Gas ●

(Constellation of Orion & M42)



Visible light: This image of the constellation shows stars of all ages and temperatures as we would see with our eyes. Can you see a faint, hazy patch? What can we find out about what this is?



Infrared: The brightest regions in infrared show where the highest concentrations of dust are. The entire region seems to glow with warm dust clouds. Is the fuzzy patch one of the brightest regions? New stars are probably forming from all this dust. Notice how some of the stars are almost invisible. Very hot stars emit most of their light in ultraviolet and visible light energies. They generate only a little energy at the cooler infrared levels. What kind of stars do you suppose are forming in the fuzzy patch?



Ultraviolet: This view of the area around the fuzzy patch shows the nebula hot with the ultraviolet light of massive young stars. Notice how brightly some of the stars shine in ultraviolet – these are the really hot stars!

Back #7

Planetary Nebula – A Dying Star ●

(M27 – Dumbbell Nebula)



Visible light: A shell of gas and dust is being expelled from an average star (like the Sun) nearing the end of its life. Our star might have a shell around it like this in a few billion years.



Infrared: Infrared light from cool dust traces the outline of the dusty cloud around the dying star. This dust is enriching space with elements like oxygen and calcium to make new stars and their planets - and maybe beings like you!



X-ray: The hot X-rays coming from the center of the planetary nebula (red in the center indicates the most intense X-rays) reveal the exposed hot core - the remains of the dying star - a white dwarf.

Source: http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m27.html

Back #8

Saturn



Visible light: In visible light we begin to see features in Saturn's atmosphere as well as in its vast ring system.



Infrared: The image shows both the planet and the rings radiating heat absorbed from the Sun. The lighter the color, the warmer the area. We can see that Saturn's south pole is warmer than its equator. The equator is about -300°F , so at -188°F , the south pole is comparatively pleasant!



Ultraviolet: Ultraviolet reveals Saturn's auroras which are over 1,000 miles above the clouds. These auroras are caused by solar wind particles guided to Saturn's polar regions by the planet's magnetic field where they collide with gases in Saturn's atmosphere—Saturn's equivalent of the Northern Lights.

Source: http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m13.html

Back #9

The Sun A close-up view of a star!



Visible light: This is the view through a telescope with a solar filter on it. What do you see? Some dark spots? Do you suppose all stars have dark spots like this? What are they? They appear dark because they are cooler than the surrounding gas which is glowing at about 6000°C . Let's look at other energies of light to find out more.



Radio: Do you notice the regions of strongest radio energy seem to correspond with the placement of the sunspots? Radio can reveal magnetic fields. Does it look like there are strong magnetic fields near sunspots?



Ultraviolet: Magnetic fields trap hot gases. The ultraviolet allows us to see hot flares and material looping out of the Sun at temperatures of up to a million degrees. Solar storms and flares, which can disrupt communications on Earth, result from changes in the magnetic fields of the Sun.

Back #10

Optical Rusty



This is Rusty.

Can you tell by just looking what parts of him are warm and which are cooler?

Front #1

Optical Rusty

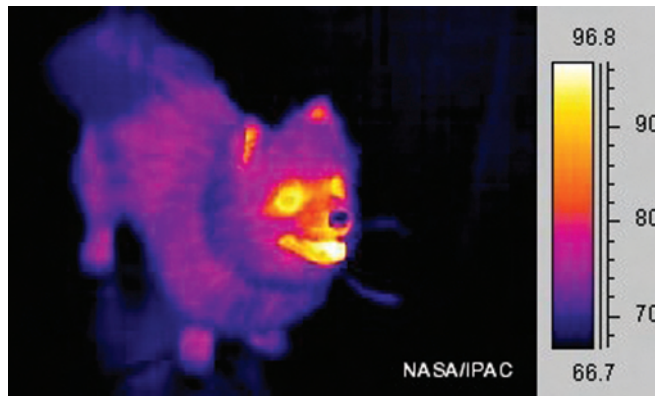


This is Rusty.

Can you tell by just looking what parts of him are warm and which are cooler?

Front #1

Infrared Rusty



REPRESENTATIONAL COLOR

This is an infrared photo that shows us where Rusty is warm and cool.

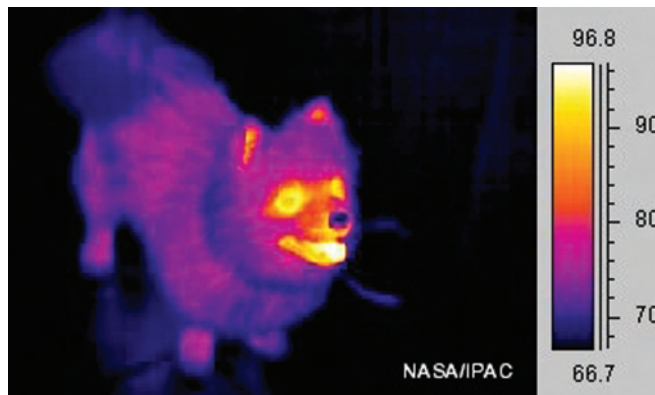
Which parts of Rusty are the warmest?

What color is being used to represent the warmest parts?

We are taking energy we can't see and converting it into something our eyes can interpret: different colors representing different temperatures.

Back #1

Infrared Rusty



REPRESENTATIONAL COLOR

This is an infrared photo that shows us where Rusty is warm and cool.

Which parts of Rusty are the warmest?

What color is being used to represent the warmest parts?

We are taking energy we can't see and converting it into something our eyes can interpret: different colors representing different temperatures.

Back #1



Can You See the Flag on the Moon?

What's this activity about?

Big Question: Answering questions from your visitors regarding how much detail the telescope can resolve, such as “Can you see the flag on the Moon?”

Big Activity: Using simple props, help the visitor understand resolution – how much detail telescopes can reveal.

Participants: Adults, teens, families with children 5 years and up
If a school/youth group, 2nd grade and higher
From one person to fifteen participants

Duration: **Setup: 1 minute**

Presentation:

- **Can you see the flag on the Moon? (2 Presentation Options):** 3 – 5 minutes
- **Magnification vs. Resolution – Moon Images:** 5 minutes

Topics Covered:

- How much detail can we see with our eyes?
- How much detail with backyard scopes?
- How much detail with Hubble or Keck?
- Understand that the difference between magnification and resolution
- Basics to consider when purchasing a telescope

Where can I use this activity?

ACTIVITY	Star Party	Pre-Star Party - Outdoors	Pre-Star Party - Indoors	Girl Scouts / Youth Group Meeting	Classroom			Club Meeting	Gen Public Presentation (Seated)	Gen Public Presentation (Interactive)
					K-4	5-8	9-12			
Can you see the flag on the Moon? Star Mask	√	√		√	√	√	√	√		
Resolution vs. Magnification: Moon images	√	√	√	√		√	√	√		

Helpful Hints

1. When speaking of the size of the telescope, you might want to avoid the use of the term “aperture” and use “diameter” instead to avoid introducing jargon your audience might not be familiar with.
2. Terms such as “arc minute” and “arc second” are difficult for the general public. Be sure they understand what you mean if you use any of these terms.

Background Information

Hold your index finger at arm's length against the sky. That's about 1 degree of sky. Close one eye. What can you cover with your finger – in this room? Outside the window? What's the farthest thing you can cover up?

A circle has 360 degrees. Each degree can be divided further into 60 minutes of arc. These are called arc minutes, abbreviated "arcmin".

A 20/20 eye has a resolution of about 1 arcmin. An arcmin is the apparent thickness of an unfolded small paper clip about 8 feet away. Close one eye – what does one arcmin cover – in this room? Outside?

1. As you increase magnification (by using different eyepieces), the amount of sky you are looking at will generally get smaller - you are looking a smaller amount of the object you are viewing. The amount of light the telescope is gathering does not change. The resolution of the telescope does not change. The area of sky the scope is collecting light from doesn't change. The eyepiece allows you to pick how much of that area of sky you want to view. It's very much like taking a photo and zooming in on a small area of that photo. Higher magnification might make it easier for your eye to perceive the detail the telescope is capable of giving you, but the telescope cannot collect any more detail (in other words, get better resolution) with higher magnifications.
2. NASA telescopes for the most part have a fixed field of view. You can "magnify" the images obtained from such telescopes by enlarging them, but you will not get any better resolution.

Resolution of the telescope

Each arc minute ("arcmin") can be divided further into 60 arc seconds, abbreviated "arcsec".

Our (amateur) telescopes generally have a lower resolution limit of one arcsec. That's about the apparent thickness of an unfolded paperclip about 160 yards away – (about one and a half times the length of a football field). The Hubble Space Telescope has a best resolution of about 0.05 arcsecs. That's about the apparent thickness of the unfolded paper clip almost 2 miles away.

(Chandra has a resolution of 0.5 arcsecs and Spitzer about 4 arcsecs.)

See the chart "**Smallest Resolvable Features**" below. This shows the smallest resolvable feature of various objects visible in telescopes.

On the same page is a list of the stars with the largest angular diameters. Since the stars for the most part are less than 1/1000 of an arcsec across, the stars are not resolvable as

disks in our telescopes since they subtend angles much smaller than one arcsec. They are bright enough to see but not big enough to resolve into a disk, like you can with a planet.

So, when your visitors look through the telescope at stars, the stars are actually going to appear smaller than when they look at them naked eye.

Our eye's smallest resolution is generally one arcmin. So the stars are going to appear to our eyes to be at least one arcmin in size. The telescope's smallest resolution is one arcsec, so the stars in the scope will appear much smaller than one arcmin, but no smaller than one arcsec. Think of a grid of pixels on a CCD chip. If we apply the pixel analogy to our eye and the telescope, our eye's "pixel" is one arcmin across and a telescope's "pixel" is one arcsec across. See the examples and discussion below under "**Why don't the stars look bigger in the scope?**"

The Keck Observatory, Adaptive Optics, & Resolution

This is from Laura Kraft, Public Information and Outreach Officer, W. M. Keck Observatory, California Association for Research in Astronomy:

We cannot see in optical bands (visible light) with adaptive optics. I explain the reason below in Note 1.

Our highest possible resolution is actually with the Keck Interferometer (see Note 2). I only mention it because we get .005 arcsecond resolution at 2.2 microns with the Interferometer (wow!), the effective resolution of the distance between Keck I and Keck II, which is the equivalent of an 85-meter telescope. The interferometer only works in near- and mid-infrared wavelengths (up to 10 microns).

Here is my best summary:

BEST RESOLUTION/Optical/AO-OFF/FOV

Limited to the seeing of Mauna Kea. Generally averages at 0.4-0.6 arcseconds. Largest field of view possible with an instrument is 16.7 arcminutes by 5 arcminutes (DEIMOS).

BEST RESOLUTION/Near Infrared/AO-OFF/FOV

Best ever seen is 0.15 arcseconds at 2.2 microns. A number affected by seeing. FOV varies, but the wide-field camera on the best instrument for Keck AO (NIRC2) is 40x40 arcsecs.

BEST RESOLUTION/Near Infrared/AO-ON/FOV

0.045 arcseconds at 2.2 microns. Wide field camera is 40x40 arcsecs.

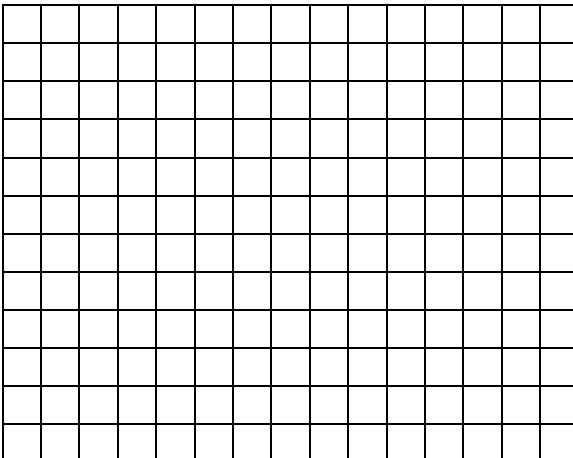
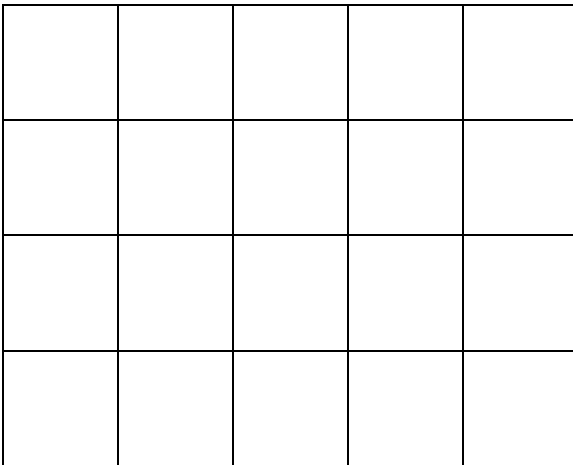
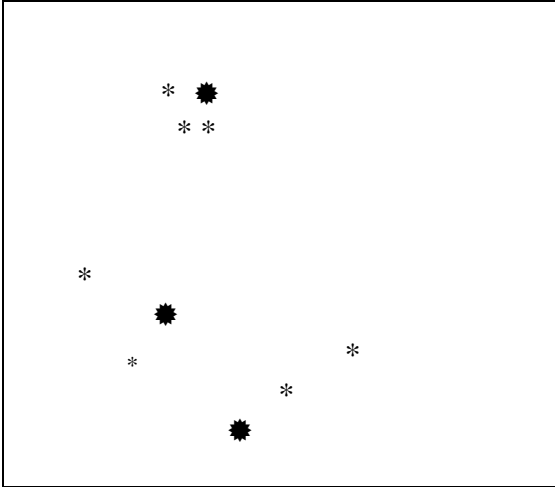
Here are the notes:

1: Visible light is taken from the focused light and used to guide the

wavefront sensor, which tells the computer what the atmosphere is doing, and then the computer knows how to correct for the longer infrared light. To use adaptive optics with visible light, (on the Keck system) you would need to feed a shorter-than-optical wavelength of light into the wavefront sensing camera so that the system could correct for visible light. In other words, to split a wavelength shorter than the one you are working with to have it guide your camera. So Keck can only look at wavelengths longer than optical with adaptive optics.

*2: Interferometers use synthesis imaging to construct an image from measurements of the object's Fourier transform function.
(<http://mathworld.wolfram.com/FourierTransform.html>).*

Why don't the stars look bigger in the scope?

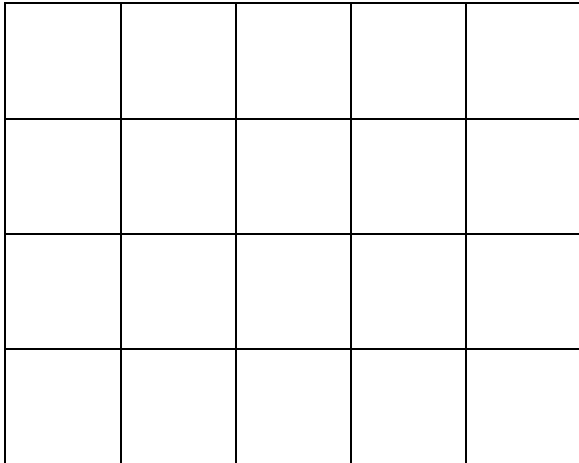


The top square on the left shows simulated sizes and locations of stars in a small area of the sky (not to scale)

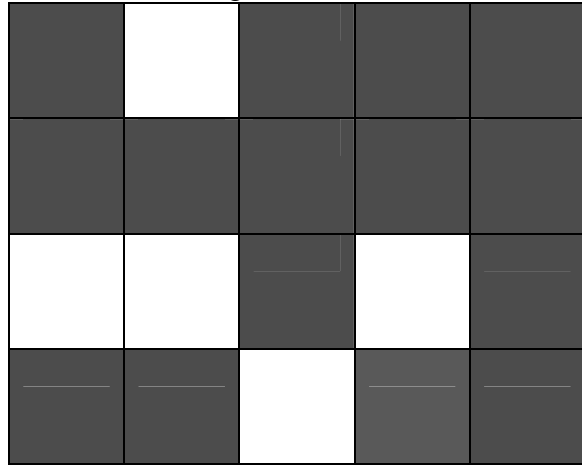
The middle grid on the left represents your eye as a CCD chip. Overlay this grid on the star field above and color in each square where there are no stars. The white squares will represent the light your eye will see.
See example next page.
 How big will the stars look with your eye? Will you be able to distinguish all the individual stars?

The bottom grid on the left represents the telescope's view as a CCD chip (not to scale!). Telescopes have a much better resolution than the eye. Overlay this grid on the star field above and fill in each square where there are no stars. The white squares will represent the light you will see in the telescope.
See example next page.
 How big will the stars look in the telescope?

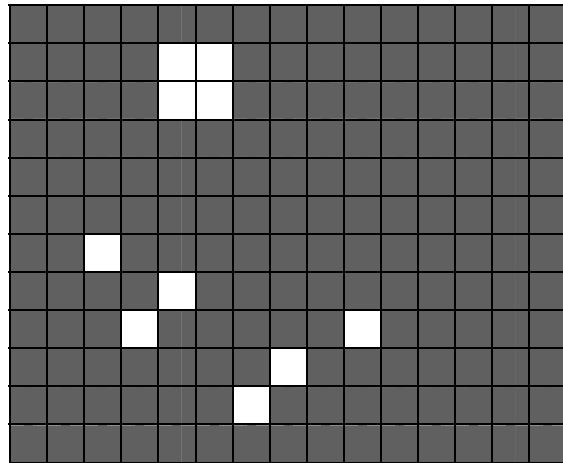
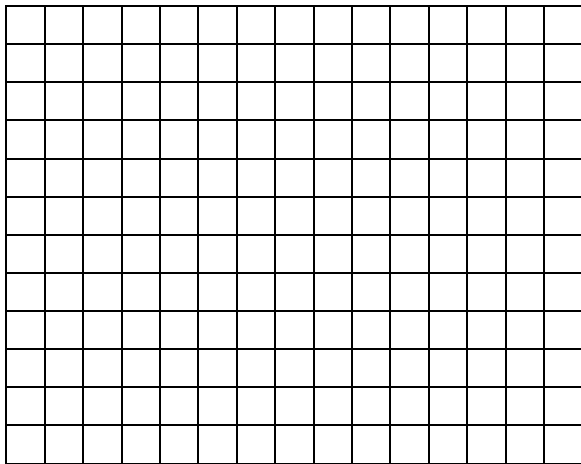
Using the “Example Star Field” below...



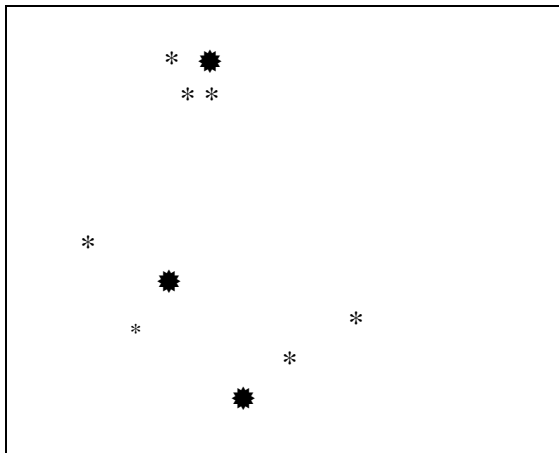
... the filled in grids would look like these.



With your eye, you'd see 5 “big” stars.



Example Star Field



With a telescope, you'd see all 10 stars and they would look smaller in the field of view.

Smallest Resolvable Features

Object	Distance from Earth	Size of 1 arcmin at distance of Object	Size of 1 arcsec at distance of Object	Hubble 0.05 arcsec
Moon	240,000 miles	60 miles	1 mile	1/20 th of a mile or about the length of a football field
Jupiter	Close approach about 425 million miles	125,000 miles (Jupiter's diameter is 88,000 miles!)	2,000 miles	100 miles
Trifid Nebula (M20)	5,200 light years	1.5 lt yrs	0.03 lt yr	9 billion miles (about twice the distance across the Solar System)
Hercules Cluster (M13)	25,000 ly	7 light years	1/10 ly	30 billion miles
Whirlpool Galaxy (M51)	37 million ly	10,000 lt yrs	150 lt yrs	7 lt yrs

1 light year is almost 6 trillion miles

At the distance of the Moon, one arcmin is about 60 miles, 1 arcsec is about a mile – the smallest crater we can see in the scope would be about 1 mile across – so can we see the flag on the Moon? No.

Size of the stars: For the most part, the angular sizes of stars are less than 1/1000th of an arcsec. Here are some with the **largest** angular diameters.

	Type	Distance (LY)	Diameter(arcsec)	Solar diameters
Betelgeuse	M1Ib	425	0.054	734.4
Antares	M1Ib	520	0.041	682.2
Proxima Centauri	dM5	4.2	0.007	1.0
Polaris	F7 Ib	430	0.00328	45

Detailed Activity Descriptions


Can you see the flag on the Moon?

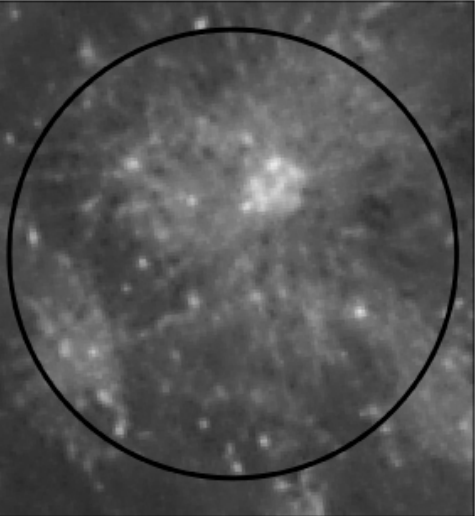
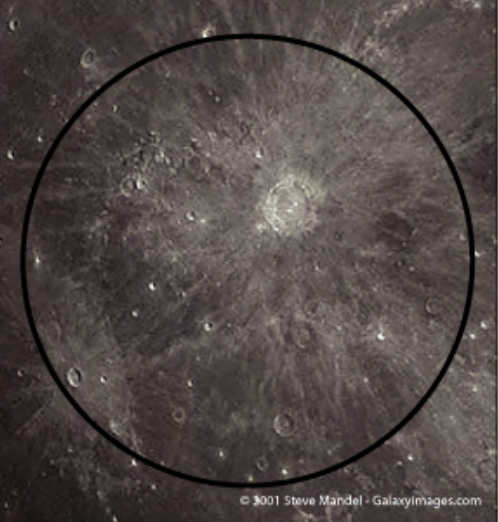
Leader's Role	Participants
<p>Key message for your visitors to take home: Observing instruments, including your eye, have limited resolution.</p>	
<p>Materials: Flashlight with star mask, telescope</p>	
<p>PRESENTATION OPTION # 1</p> <p><u>To Do:</u> Stand at least 20 feet (6 meters or about 6 – 7 paces) away from your visitors. Shine the flashlight covered with the star mask toward your visitors.</p> <p><u>To Say:</u> How many stars do you see?</p>  <p><u>To Do:</u> Move forward toward your visitors with the flashlight until you are about five feet (1.5 meters) away from them.</p> <p><u>To Say:</u> Now how many stars do you see?</p>  <p>Just like your eyes have a limit to how much detail they can resolve at a particular distance, telescopes do too. At the distance of the Moon, the smallest feature your eye alone can resolve is about 60 miles (100 km) across.</p>	<p>Can you see the flag/footprints on the Moon?</p> <p>Say number.</p> <p>Say larger number.</p>

<p><i>To Say:</i> Backyard telescopes can generally do about 30 – 60 times better than your eyes. Under the best of conditions, like dark skies and steady air, we might even do better than that. This scope can generally get about 60 times better resolution, so at the distance of the Moon, the smallest feature this telescope could resolve would be how big? Right 1 mile. How big is a flag? About 3' x 5' Can we see the flag on the Moon with this telescope?</p> <p>The Hubble can see about 1,200 times more detail than our eyes. At the distance of the Moon, that's about the length of a football field.</p> <p>Would the Hubble be able to see the flag? We would need a telescope with 60,000 times better resolution than our eyes to see something as small as a flag on the Moon! That would have to be a telescope out in space with a diameter of over 450 feet! (one and a half football fields or the height of a 45 story building). But take a look through the scope and tell me what you can see!</p>	<p>About a mile. Smaller than that. No.</p> <p>Can the Hubble telescope see the flag? No.</p>
<p>Presentation Tip: See the discussion under “Background Information” about adaptive optics on the Keck telescope on Mauna Kea in Hawaii.</p>	

Leader's Role	Participants' Roles (Anticipated)
<p>Key message for your visitors to take home: Observing instruments, including your eye, have limited resolution.</p>	
<p>Materials: Flashlight with star mask, telescope.</p>	
<p>PRESENTATION OPTION # 2</p> <p><u>To Do:</u> Place the flashlight with star mask about 50-60 feet away (about 3 to 4 car lengths or about 15 – 20 paces) on a table or chair. Turn on the flashlight. Set up a telescope to point at the flashlight.</p> <p><u>To Say:</u> See that light over there? It represents a field of stars. How many stars do you see? Let's see if the telescope can allow you to distinguish more stars.</p> <p><u>To Do:</u> Have each visitor view flashlight through telescope.</p> <p><u>To Say:</u> How many stars do you see now?</p> <p>These telescopes have much better resolution than our eyes do – about 60 times better. You can see with the telescope from 60 feet away the same that you'd see with your eye from one foot away.</p> <p>Look at the Moon. At the distance of the Moon, the smallest feature your eye alone can resolve is about 60 miles (100 km) across. Since this scope can generally get about 60 times better resolution than your eye, at the distance of the Moon, the smallest feature this telescope could resolve would be how big? Right 1 mile. So can we see a 3-foot by 5-foot flag on the Moon with this telescope?</p> <p><u>To Do:</u> If the Moon is visible, re-position your telescope on the Moon. Have each visitor view the Moon through the telescope.</p> <p><u>To Say:</u> Tell me what you CAN see.</p>	<p>Say number.</p> <p>Say larger number.</p> <p>A mile.</p> <p>No.</p>

MAGNIFICATION vs. RESOLUTION

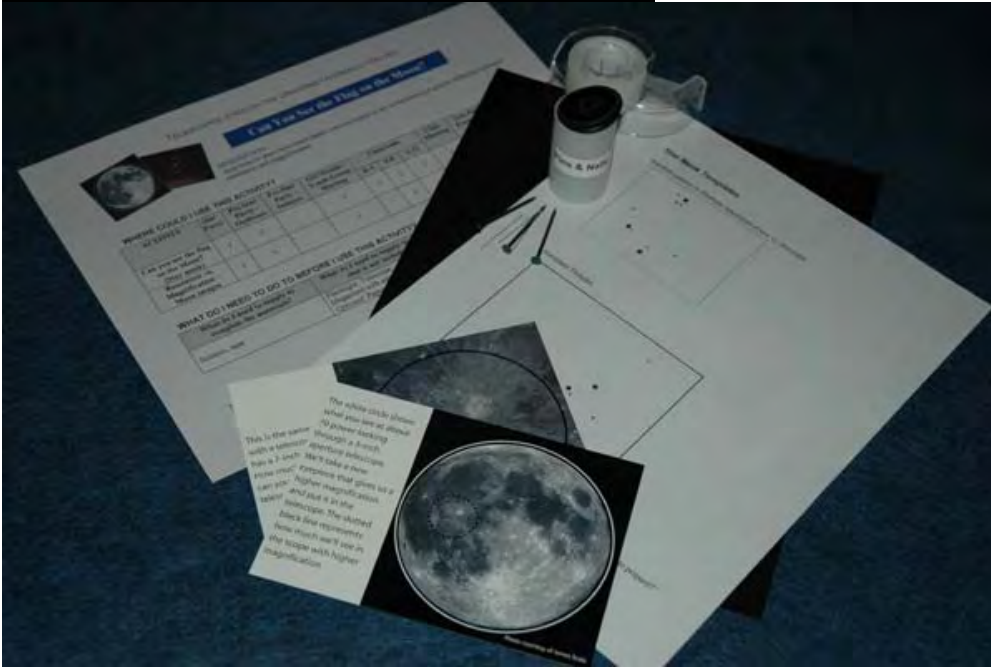
Leader's Role	Participants' Roles (Anticipated)
<p>Key message for your visitors to take home: Magnification is determined by the eyepiece used, not by the size of the telescope. Resolution – or how much detail you can see – depends primarily on the aperture of the telescope (assuming the equal quality of the primary lens or mirror). Higher magnification might make it easier for your eye to perceive the detail the telescope is capable of giving you, but the telescope cannot collect any more detail (in other words, get better resolution) with higher magnifications.</p>	
<p>Materials: Moon image cards or “MoonMagnify.ppt” PowerPoint Optional (you supply): paper towel tubes.</p>	
<p><u>To Do :</u> Show the full moon image to your visitors.</p> <div data-bbox="240 699 987 1224" style="border: 1px solid black; padding: 5px;"> <p>The white circle shows what you see at about 70 power looking through a 3-inch aperture telescope. We'll take a new eyepiece that gives us a higher magnification and put it in the telescope. The dotted black line represents how much we'll see in the scope with higher magnification.</p>  <p style="text-align: right; font-size: small;">Photo courtesy of James Scala</p> </div> <p>(Optional) Have your visitors look through a paper towel tube to simulate looking through a telescope.</p> <p><u>To Say:</u> The white circle around the Moon shows what you see at a magnification of about 70 times looking through a 3-inch aperture telescope. What are we looking at?</p> <p>Do you think we'll see a lot more detail if we magnify this? We'll take a new eyepiece that gives us higher magnification and put it in the telescope. The dotted black line represents how much we'll see in the scope with under higher magnification. Let's see what that looks like.</p>	<p>The Moon!</p> <p>Yes.</p>

Leader's Role	Participants' Roles (Anticipated)
<p><u>To Do:</u> Show the card with the close-up of the moon in the 3" scope.</p> <div data-bbox="240 317 483 829" style="display: inline-block; vertical-align: top; width: 25%;"> <p>The circle represents our view through the telescope. This represents a magnification of about 300X. The resolution of the telescope does not get any better! For better resolution, you need a larger aperture telescope with a high-quality mirror. Let's look at this same area of the Moon through a telescope with a larger aperture.</p> </div>  <p><u>To Say:</u> The circle represents our view through the telescope. This represents a magnification of about 300X. How do you like this? The resolution of the telescope does not get any better. For better resolution, you need a larger aperture telescope with a high-quality lens or mirror. Let's look at this same area of the Moon through a telescope with a larger aperture and a high-quality lens.</p>	<p>It's OK. Pretty fuzzy.</p>
<p><u>To Do:</u> Show the card with the Moon image from the 7" scope.</p> <div data-bbox="240 1241 483 1759" style="display: inline-block; vertical-align: top; width: 25%;"> <p>This is the same view with a telescope that has a 7-inch aperture. How much more detail can you see with this telescope?</p> </div>  <p><u>To Say:</u> This is the same view with a telescope that has a 7" aperture. How much more detail can you see with this one?</p>	<p>A lot!</p>

Leader's Role	Participants' Roles (Anticipated)
<p><u>To Say:</u> Although other telescope characteristics, like magnification, are sometimes referred to as the telescope's "power", the "power" of the telescope is not how much the image is magnified. It is primarily the size of the primary lens or mirror - how big around the telescope is.</p> <p>So when you go to buy a telescope, pay more attention to the diameter, or aperture, of the telescope and the quality of the mirror or lens, not the claimed magnification. Larger diameter telescopes collect more light from the object you are viewing. The diameter, or aperture, of the telescope is one of the primary factors that determines how bright the image is and how much detail you will see when you use an eyepiece to magnify the view.</p>	
<p><u>Presentation Tip:</u> Here is additional information to help your visitors understand:</p> <p>As you increase magnification, the amount of sky you are looking at generally gets smaller* - you are looking at a smaller amount of the object you are viewing. The amount of light the telescope is gathering does not change. The resolution of the telescope does not change. The eyepiece allows you to pick how much of that area of sky you want to view. Higher magnification might make it easier for your eye to perceive the detail the telescope is capable of giving you, but the telescope cannot collect any more detail (in other words, get better resolution) with higher magnifications.</p> <p>*Different eyepieces with the same focal length or magnification can have different fields of view. For example, after looking at the moon through a low-magnification eyepiece that allows you to see the entire disk of the moon, it is possible to switch eyepieces to one with both a higher magnification and a larger field of view, enabling you to still see the whole moon, but at higher magnification. The field of view decreases as the magnification increases only if the two (low- and high-magnification) eyepieces are the same type.</p>	

Materials

What materials from the ToolKit do I need?



In the “Can You See the Flag on the Moon?” activity bag:

1. Black construction paper (used to make the “star mask”)
2. Template for star mask patterns
3. Film canister with pins and nails.
4. Adhesive tape
5. Moon Images Cards

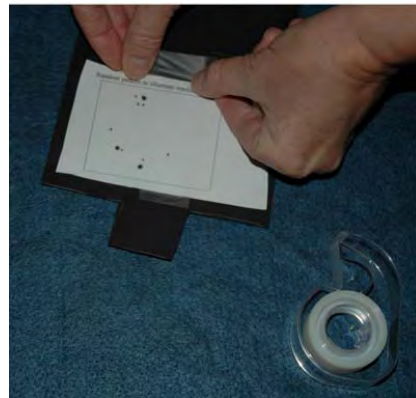
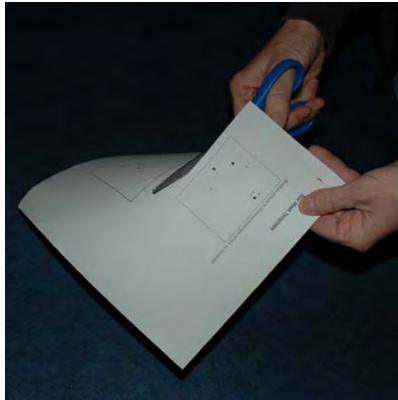
In the “PowerPoints” folder on the Manual & Resources CD:

1. MoonMagnify.ppt

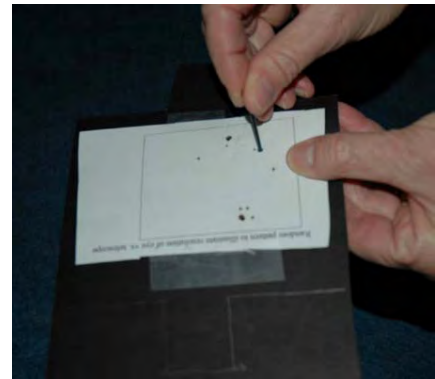
What do I need to prepare?

To make your star mask(s):

- a) Open the film canister labeled “Pins and Nails”.
- b) Place your flashlight on the black construction paper and draw a square that will cover the front of your flashlight, allowing for a tab (see photo >).
- c) Cut out the Star Mask Template pattern and lay it on the square. Tape the template to the construction paper.



- d) Use the nail to punch the larger holes and the straight pin to poke the small holes. (see photo >)
- e) Remove the template.
- f) Tape the star mask over the front of your flashlight.



What must I supply?

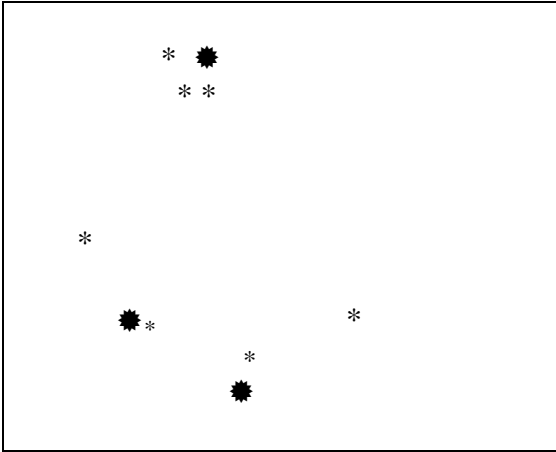
- Flashlight
- Scissors
- Optional: Paper towel tubes

Where do I get additional materials?

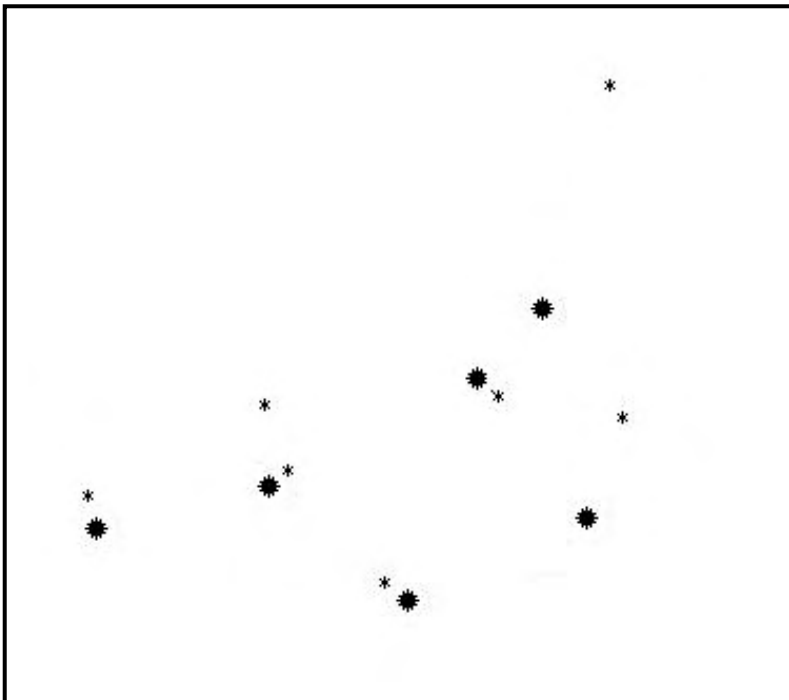
1. Black construction paper: office supply
2. Adhesive tape: office supply
3. Star Mask Templates - next page
4. Moon images: print from “Moon Images” pages in the ToolKit Manual

Star Mask Templates

Random pattern to illustrate resolution of eye vs. telescope



Simulates Pleiades



For instructions on making and using Star Masks, see the section “What do I need to prepare?” (on the previous page)

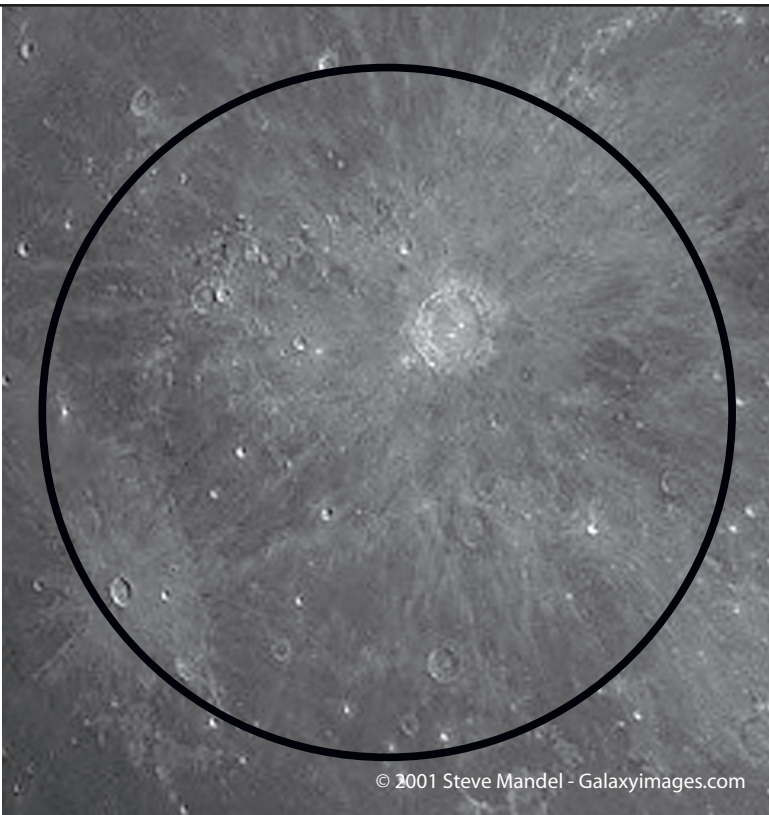
Moon Magnify: Sheet A

The white circle shows what you see at about 70 power looking through a 3-inch aperture telescope. We'll take a new eyepiece that gives us a higher magnification and put it in the telescope. The dotted black line represents how much we'll see in the scope with higher magnification.



Front #1

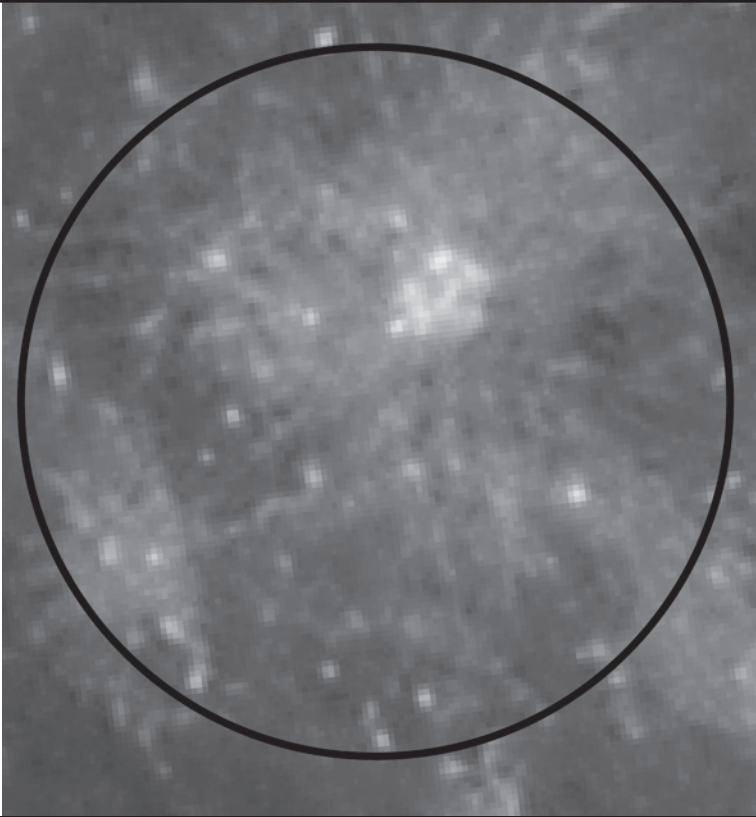
This is the same view with a telescope that has a 7-inch aperture. How much more detail can you see with this telescope?



Front #2

Moon Magnify: Sheet B

The circle represents our view through the telescope. This represents a magnification of about 300X. The resolution of the telescope does not get any better! For better resolution, you need a larger aperture telescope with a high-quality mirror. Let's look at this same area of the Moon through a telescope with a larger aperture.



Back #1

Although other telescope characteristics, like magnification, are sometimes referred to as the telescope's "power," the "power" of the telescope is not how much the image is magnified. It is primarily the size of the primary lens or mirror – how big around the telescope is.

So when you go to buy a telescope, pay more attention to the diameter, or aperture, of the telescope and the quality of the mirror or lens, not the claimed magnification. Larger diameter telescopes collect more light from the object you are viewing. The diameter, or aperture, of the telescope is one of the primary factors that determines how bright the image is and how much detail you will see when you use an eyepiece to magnify the view.

Back #2

TELESCOPES: EYES ON THE UNIVERSE OUTREACH TOOLKIT



Media & Resources

TELESCOPES: EYES ON THE UNIVERSE OUTREACH TOOLKIT - GETTING STARTED -

1. INSERT “MANUAL & RESOURCES” CD INTO YOUR COMPUTER. Click on 0ScopeManual.pdf to navigate through the Outreach ToolKit Manual. You need the free Adobe Acrobat Reader to view the manual:
<http://www.adobe.com/products/acrobat/readstep2.html> .
2. For best results copy the entire CD onto your computer hard drive in any folder you choose.
3. VIEW THE TRAINING VIDEO as you review materials in the ToolKit – this is a DVD labeled “Training”.
4. Review the PowerPoints in the “PowerPoints” folder on the ToolKit Manual and Resources CD.
5. Review “Telescopes from the Ground Up” website in the “Telescopes Ground Up Website” folder on the ToolKit Manual and Resources CD. Click on “index.htm” to run the website. For system requirements, click on “computerneeds.html”.
6. Questions? Contact nightskyinfo@astrosociety.org

WHERE COULD I USE THE ANIMATIONS AND OTHER RESOURCES INCLUDED HERE?

MEDIA / RESOURCE	Pre-Star Party - Indoors	Girl Scouts / Youth Group Meeting	Classroom			Club Meeting	Gen Public Presentation (Seated)
			K-4	5-8	9-12		
<i>PowerPoint: TelescopeChgUniv.ppt</i>	√	√		√	√	√	√
<i>Telescopes from the Ground Up website</i>	√	√		√	√	√	√
<i>PowerPoint: MoonMagnify.ppt</i>	See the activity “Can You See the Flag on the Moon?”						
<i>PowerPoint: NotLikePhotos.ppt</i>	See the activity “Why Doesn’t It Look Like the Photos?”						

NASA Structure and Evolution of the Universe Forum <http://cfa-www.harvard.edu/seuforum/>
 NASA Origins Education Forum <http://origins.stsci.edu>
 JPL Navigator Public Engagement Program: <http://planetquest.jpl.nasa.gov/index.html>
 SETI Institute under NASA Grant NAG 2-6066 for the Kepler Mission <http://www.kepler.arc.nasa.gov/>





What Power is Your Telescope?

DESCRIPTION: Using a few simple props, show the basics of how telescopes work. Includes quick, simple demos that can be done at the telescope.

See Outreach ToolKit Manual and Training Video for assembly and suggested presentation scripts.

WHERE COULD I USE THIS ACTIVITY?

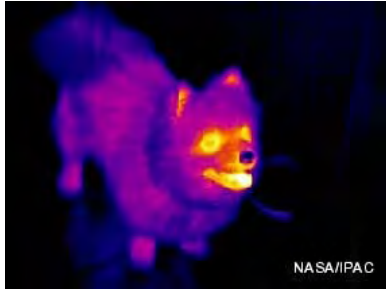
ACTIVITY	Star Party	Pre-Star Party - Outdoors	Pre-Star Party - Indoors	Girl Scouts / Youth Group Meeting	Classroom			Club Meeting	Gen Public Presentation (Seated)	Gen Public Presentation (Interactive)
					K-4	5-8	9-12			
Light Spreads Out with Distance	√	√	√	√	√	√	√	√	√	
How do telescope work?	√	√	√	√	√	√	√	√	√	
How big are telescopes NASA uses?		√	√	√	√	√	√		√	

WHAT DO I NEED TO DO TO 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
Adhesive tape Tape measure Pencil or paper towel tube to roll string up	<i>Optional:</i> More vermiculite or sand	Assemble foam and sticks Affix the telescope labels to the string at the appropriate distances

NASA Structure and Evolution of the Universe Forum <http://cfa-www.harvard.edu/seuforum/>
 NASA Origins Education Forum <http://origins.stsci.edu>
 JPL Navigator Public Engagement Program: <http://planetquest.jpl.nasa.gov/index.html>
 SETI Institute under NASA Grant NAG 2-6066 for the Kepler Mission <http://www.kepler.arc.nasa.gov/>





Why Doesn't it Look Like the Photos?

DESCRIPTION:

Two activities to show why images we see in the telescope do not look like the pictures in magazines. Why NASA needs different kinds of telescopes to help us understand the universe.

See Outreach ToolKit Manual and Training Video for assembly and suggested presentation scripts.

WHERE COULD I USE THIS ACTIVITY?

ACTIVITY	Star Party	Pre-Star Party - Outdoors	Pre-Star Party - Indoors	Girl Scouts / Youth Group Meeting	Classroom			Club Meeting	Gen Public Presentation (Seated)	Gen Public Presentation (Interactive)
					K-4	5-8	9-12			
Exposure time		√	√	√	√	√	√		√	
Representational Color Intro (Rusty and USA cards)		√	√	√		√	√		√	
Universe in a Diff Light Game		√	√	√		√	√		√	

WHAT DO I NEED TO DO TO 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
Scissors Knife White glue	<i>Optional:</i> Newspapers or tablecloth.	View Training Video or refer to the Manual under "What do I need to do to prepare?"

NASA Structure and Evolution of the Universe Forum <http://cfa-www.harvard.edu/seuforum/>
 NASA Origins Education Forum <http://origins.stsci.edu>
 JPL Navigator Public Engagement Program: <http://planetquest.jpl.nasa.gov/index.html>
 SETI Institute under NASA Grant NAG 2-6066 for the Kepler Mission <http://www.kepler.arc.nasa.gov/>





Can You See the Flag on the Moon?

DESCRIPTION:

Activities to show how much detail you can expect to see in the telescope and the difference between resolution and magnification.

WHERE COULD I USE THIS ACTIVITY?

ACTIVITY	Star Party	Pre-Star Party - Outdoors	Pre-Star Party - Indoors	Girl Scouts / Youth Group Meeting	Classroom			Club Meeting	Gen Public Presentation (Seated)	Gen Public Presentation (Interactive)
					K-4	5-8	9-12			
Can you see the flag on the Moon? (Star mask)	√	√		√	√	√	√	√		
Resolution vs. Magnification – Moon images	√	√	√	√		√	√	√	√	

WHAT DO I NEED TO DO TO 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
Scissors, tape	Flashlight, Telescope Magazines with astronomy photos <i>Optional:</i> Paper towel tubes	Make star mask and attach to your flashlight. See instructions in the Manual.

NASA Structure and Evolution of the Universe Forum <http://cfa-www.harvard.edu/seuforum/>
 NASA Origins Education Forum <http://origins.stsci.edu>
 JPL Navigator Public Engagement Program: <http://planetquest.jpl.nasa.gov/index.html>
 SETI Institute under NASA Grant NAG 2-6066 for the Kepler Mission <http://www.kepler.arc.nasa.gov/>



TELESCOPES: EYES ON THE UNIVERSE OUTREACH TOOLKIT



Ready to Observe?

DESCRIPTION: This set of activities helps answer common questions we get at the telescope and provides tools to help your visitors understand what to expect and how to enhance their experience: Why don't I see any color? Where are you looking? How much of the sky are we seeing in the scope? Why is the image upside down? What do you mean by "averted vision"?

WHERE COULD I USE THIS ACTIVITY?

ACTIVITY	Star Party	Pre-Star Party - Outdoors	Pre-Star Party - Indoors	Girl Scouts / Youth Group Meeting	Classroom			Club Meeting	Gen Public Presentation (Seated)	Gen Public Presentation (Interactive)
					K-4	5-8	9-12			
Why don't I see any color?	√		√	√	√	√	√			
Averted Vision	√	√	√				√			
Field of View (FOV) Card	√	√	√	√	√	√	√		√	
Why is the image upside down?	√	√	√	√	√	√	√		√	

WHAT DO I NEED TO DO TO 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
<i>Optional:</i> Stickers with your club info for the FOV cards; Magazines with astronomy photos	Telescope <i>Optional:</i> More spoons Instructions for ordering more FOV cards are in the Manual.	Use pin to poke a hole in each FOV card for the Hubble Telescope field of view Assemble foam and sticks

NASA Structure and Evolution of the Universe Forum <http://cfa-www.harvard.edu/seuforum/>
 NASA Origins Education Forum <http://origins.stsci.edu>
 JPL Navigator Public Engagement Program: <http://planetquest.jpl.nasa.gov/index.html>
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