Ready to Observe?

How to Enhance Your Experience at the Telescope

About the Activity

Using a variety of simple props, help the visitor at the scope understand why they see what they see. Learn about how the eye works, how to use the most powerful part of the eye to see more detail, and what to expect out of an experience observing through a telescope.

Topics Covered

- Why don't I see any color?
- What is "averted vision"?
- How much of the sky are we seeing in the telescope?

Materials Needed

- **To print** (card stock for durability):
  - Enough Field of View (FOV) cards for each participant to have one
  - At least one copy of color squares/averted vision card (or one at each telescope)
- Regular ¼" hole punch
- 16-penny nail
- small nail or push-pin
- straight pin
- Scissors
- *Optional:* Pictures or posters of astronomical images

Participants

Adults, teens, families with children 5 years and up. If using with a school/youth group, age 7 and older. From one person to fifteen participants

Location and Timing

These activities are perfect for use at a star party, with youth groups, or in the classroom. For exploring "Why Don't I See Any Color?" you will want a dark environment, either inside or outside. Each takes just a few minutes.

Included in This Activity

Set Up Instructions
Detailed Activity Description
Helpful Hints
Background Information
Field of View cards
Color Squares/Averted Vision cards

Additional astronomy activities can be found here: http://nightsky.jpl.nasa.gov

Set Up Instructions

1) Print out Field of View (FOV) cards on card stock.
2) Punch a hole for the “Backyard telescope” with a regular 1/4” hole punch.
3) Poke a hole for Arecibo using a 16-penny nail.
4) Poke a hole for Spitzer using a small nail or push pin.
5) Poke a hole for the Hubble using a straight pin.
6) For the larger holes, you can fold the card at the hole and cut out the dark circles (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.

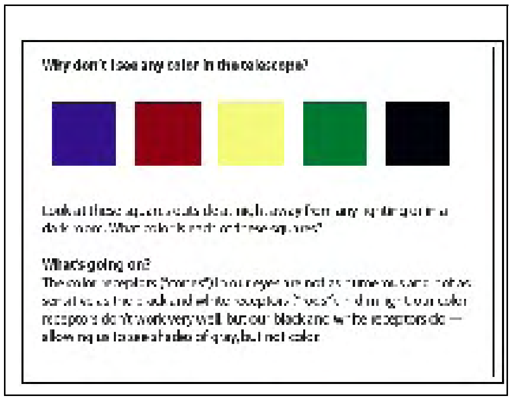
Detailed Activity Description

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)**
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.	
Materials: Magazines with astrophotos	
To Do: Show magazines, slides, or posters of photos of celestial objects. *To Say:* Are you expecting to see this in the telescope? 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. Your eyes work very differently from a camera that would produce photos like these. 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.	Maybe. Yes. Not sure.

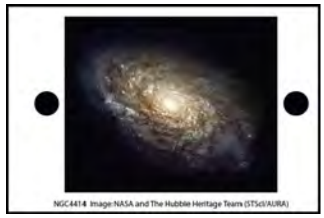
Color: Why don't I see any color?

Leader's Role	Participants' Roles (Anticipated)
Key message for your visitors to take home: Eyes can only see black and white in dim light.	
Materials: Card with color squares.	
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.	
Question from visitor at the scope: Why don't I see any color?  *To Do:* Hand the visitor the color card. *To Say:* What color is each of these squares?	Not sure. They all look gray.
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. *To Do:* Shine a dim white light on the card or bring the card to a place with more light. *To Say:* Now what color are they?	Oh, I see now.
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.	

Leader's Role	**Participants' Roles (Anticipated)**
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.	
To Say: 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. 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.	Yes. A few minutes.

Averted Vision Exercise

Leader's Role	**Participants' Roles**
Key message for your visitors: Look to the side of a dim object to see more detail in the telescope.	
SET-UP: This can be done at the telescope, or you can prepare your visitors beforehand for their observing experience by training them in the use of averted vision. The visitors might actually experience the effect on the card if you do this in a darkened room.	

To Say: *[Visitor is viewing a nebula, galaxy, or other dim object in the telescope]*	
You are looking at a pretty dim object and only a little of its light is reaching us. Would you like me to show you a way to help your eye detect more of the light and to see more detail?	Sure.
We'll use a technique called averted vision. Let me show you what that is.	OK
To Do: Hand the visitor the Averted Vision card. And point to the galaxy image on the card.  	
To Say: Let's say you're looking at this galaxy in the telescope. Close one eye. Look directly at the image. Now 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). The image on the card might appear a little brighter, but when you use this technique at the eyepiece, the effect is enhanced. Try looking into the telescope eyepiece, look to the side away from your nose about as close to the object as the dot is to this photo. The object you are viewing will look brighter and you'll see more detail.	Visitor tries it out. Wow! It is better.
What's going on? Your eye has a lens that focuses light onto an area that then sends a message to the brain. That area has two different kinds of light receptors. One type for color and one type for black & white. They are not evenly scattered about. More color detectors are in the center and more black & white detectors are around the edge. Since your eye's color receptors don't work as well in dim light as your black & white receptors, you don't see much when you look right at it with the insensitive color receptors but when you look to the side you are centering the image on your more sensitive black & white receptors. That's using averted vision. If you look in the direction of the dot *toward* your nose, you are centering your eye's "blind spot" over the image, making it disappear! Avert your vision in the correct direction!	

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

Leader's Role	**Participants' Roles (Anticipated)**
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.	
Materials: Field of View Card	
<u>*Question from visitor at the telescope:*</u> Where are you looking? How much of the sky am I looking at in the telescope? <u>*To Say:*</u> How much of the sky do you think we're looking at? Show me with your hands.	Guesses.
<u>*To Do:*</u> Hand the Field of View card to your visitor.  <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.	Wow! That's small!

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2009

To Say : 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? 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. 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.	What are the rest of these holes? Wow – I can hardly see anything in there.

Additional at-the-telescope activity: *To Do:* 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. *To Say:* 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.	Visitor holds card out. Visitor looks thru scope. A lot more! I think the hole is too small.
To Say: Where's the Moon? Hold the card out at arm's length. Can you get the Moon in that hole? *To Do:* Move telescope to the Moon. *To Say:* Let's look through the telescope. Are you seeing about the same amount of the Moon in the scope as through that hole?	Visitor find Moon. Yes! Weird. Yeah!

Presentation Tip #1:
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!

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.

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.

Presentation Tip #2:
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.

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

The 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 is 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.

Averted Vision

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/

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.

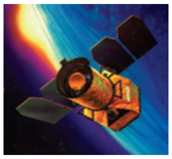
If you choose to avert your gaze downward, you will find your averted vision slightly less sensitive again. In actuality, the retina is every bit as sensitive here as it is if you avert your vision upward, but it is sensitive over a much smaller area. Thus, it is harder to consistently rest the image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

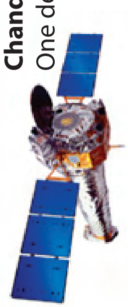
Next time you are out with your binoculars or telescope, take some time to explore these different areas of your vision. It might be quite apparent what is the most promising averted vision method for you. And if it happens to be something other than what medical science predicted, don't let that stop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

Field of Vision: 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)

Image courtesy of the NAIC

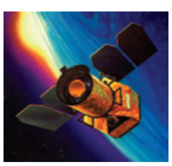
Arecibo (Radio)
1/4 degree (15 arcmins)
(See **NOTE** on back)

Spitzer (Infrared)
5 arcmins

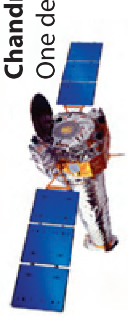
Hubble (Visible)
3 arcmins

Front #1

How much sky can the telescope see?



GALEX (Ultraviolet)
1.2 degrees



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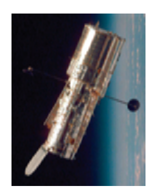

Hubble (Visible)
3 arcmins

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Front #1

Field of Vision: Sheet B

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

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Back #1

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

Averted Vision: Sheet B

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

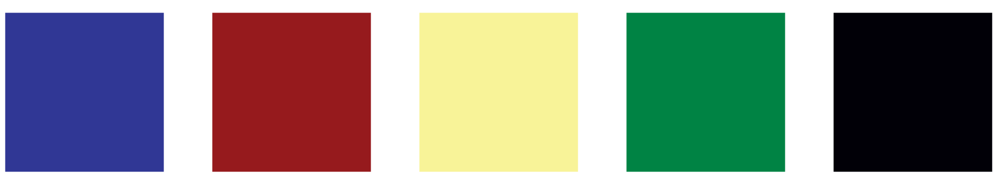
Look at these squares outside at night away from any lighting or in a dark room. What color is each of these squares?

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?



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Back #1