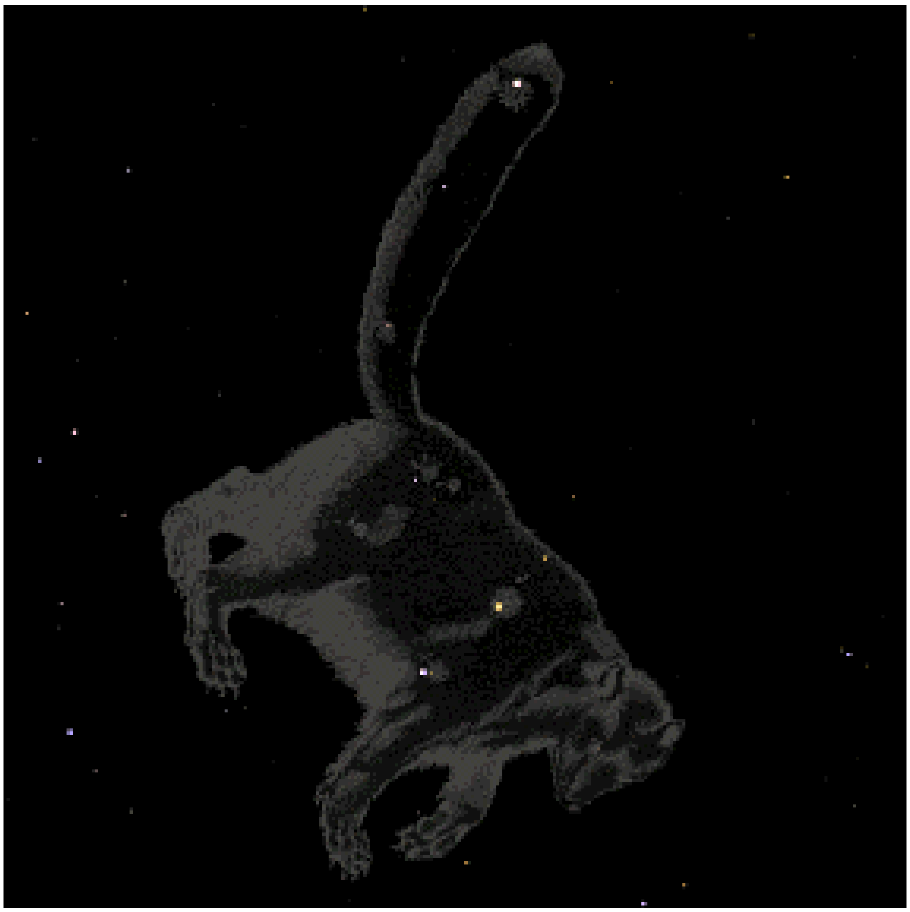
The Stars In Your Back Yard



Ursa Minor – The Little Bear

The Little Bear shows us a path of discovery in the night sky.

Onward the kindred Bears, with footsteps rude,
Dance round the pole, pursuing and pursued.

- Erasmus Darwin, grandfather of Charles Darwin

The following Activities and Lessons are brought to you by:

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Contents of This Booklet

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Activities to learn about stars, night vision, and light pollution

Teacher's Overview

The Flagstaff Dark Skies Coalition and the Willow Bend Environmental Education Center have prepared the following activities to help increase awareness about the night sky and light pollution. These activities are most naturally suited to science units on astronomy, but can also be used in units exploring pollution or environmental issues; human perception or vision; biology (nocturnal activity of animals and effects of night light on plants and animals); or mythology.

The activities help meet Arizona State Standards 1-E3, 3-F3, 5-F2, 5-F4, 1-P3, 1-P6, 1-D1, 3-P1, 3-D1, and can enhance instruction designed to meet standards 6-F2, 6-F4, 6-E1, and 6-E2. The activities are designed for grade levels 4 and above, and may be adapted to meet the needs of your classroom.

Background Information

What Is Light Pollution?

Light pollution is light where it is not needed or wanted. This unwanted light appears

- ☆ in the sky, causing sky glow
- ☆ shining into your yard or through your windows into your house, causing "light trespass"
- ☆ shining into your eyes, causing glare

That light can cause pollution is a new idea for most people, and many may think it is not really very important except to astronomers. But light pollution interferes with living systems in many ways, causing, for example, sea turtles to lose their way to the sea, migrating birds to become confused and strike buildings, and plant seasonal cycles to be disturbed. It also affects human hormone cycles and our day-and-night cycles of sleep and wakefulness. Using light carelessly wastes energy, resources used to make the energy, and interferes with everyone's visibility not only of stars but also of things on the ground that we need to see.

Stray light, in the sky or elsewhere, is wasted light – it is not needed for and does not help visibility. It is really a mistake that it is there. Why does it happen? It happens mostly because people don't think about it. Light fixtures that are poorly designed waste light by letting it shine upward or to the side, causing sky glow, light trespass, and glare. These fixtures are everywhere, at our homes and businesses, even in Flagstaff where we are more careful than most towns with our lights.

Why Does It Matter?

Though astronomers need naturally dark skies to see and learn about faint and distant objects in the Universe, dark skies are valuable for everyone – they have been a source of beauty and inspiration to all of Humankind for as long as people have been aware enough to raise their eyes from the ground and wonder. And light that provides visibility without waste or glare is vital for vision for everyone. Unfortunately, research is showing that in the U.S.A. fully two-thirds of us live under skies so bright we have lost the view of the Milky Way. And this loss comes mostly from just plain bad lighting – lighting that is not even doing a good job of showing us things we need or want to see on the ground.

What Can We Do About Light Pollution?

Unlike other forms of pollution, light pollution is easy to fix. Good-quality lighting produces very little pollution – it follows very simple principles: it puts the **right amount** of light, in the **right place**, and at the **right time**. Well-designed light fixtures, for our homes and businesses, properly located and installed, put the right amount of light onto the ground where and when we need it – not into the sky, not into our eyes. It really is that simple!

In these activities we will have students learn about the stars in the northern sky while they measure the light pollution in their back yards by counting how many stars they can see in a small part of one constellation. They will compare their view to other students in their class, and with the help of the Flagstaff Dark Skies Coalition, to other locations throughout the Flagstaff area (see the request at the end of Activity 2). Where is the North Star? Where can we see the most stars? Where do we have the most light pollution?

What Happens When Our Eyes Adapt to the Dark?

The human eye is a marvel in its ability to provide vision under a tremendous range of conditions, from full sunlight to full moonlight and less – a range of a million times in brightness! How do they do it?

First and simplest, when light levels change the *size of our pupils* changes to allow more or less light into the eye. This change is quite quick, especially in young people, taking only a few seconds. When going from bright to dark conditions it can allow about seven times more light to enter the eye.

But the biggest change in sensitivity comes from another effect that fewer people are aware of – chemical changes in the light-sensitive tissue of the eye (the retina). When light falls onto the retina, it causes a change in chemicals there. These chemicals are called "photopigments." This chemical change causes a nerve impulse to be sent to the brain, and the brain interprets these nerve messages to allow us to see. When we enter dark conditions, the eyes produce a special photopigment called "visual purple." The longer we are in dark conditions, the more visual purple is produced, and the fainter light we can see. This buildup of visual purple takes much longer than changes in pupil size, requiring half an hour or more to reach maximum sensitivity. This process can increase the sensitivity by more than a thousand times compared to the sensitivity in bright conditions.

Why Is Peripheral Vision More Sensitive When Looking at Stars?

There are two types of cells in our retinas that are sensitive to light and that allow us to see. They are called "rods" and "cones" after their shapes. The cones allow us to see colors in bright lighting conditions; the rods are sensitive in very faint light conditions but cannot perceive color. In the center of our vision, where we use the area of the retina called the "*fovea centralis*," there are lots and lots of cone cells, allowing us to see color and fine details, but there are almost no rods. Outside of the *fovea centralis* there are fewer light-sensitive cells of all types, but most of them are rods. This is why under very dark conditions, where rods are active but cones are not, we cannot see very well in the center of our vision (we cannot read, for example, or see colors), but our peripheral vision (using the rods) is very sensitive.

Activities

Goals

Students will learn:
- ☆ To identify the Big Dipper (*Ursa Major*), the Little Dipper (*Ursa Minor*), and the North Star (*Polaris*).
- ☆ That they can see fainter stars if they use their "peripheral vision."
- ☆ That the sensitivity of their eyes in dark conditions increases with time (their eyes adapt to the dark).
- ☆ How the number of stars they can see depends on how long they let their eyes adapt to the dark and how much light pollution there is.
- ☆ To compare the results of their class with other classes in the Flagstaff area. Where are the most light-polluted skies in Flagstaff? Where are the starriest skies?

Vocabulary

averted vision	Using *peripheral vision* to see, especially very faint objects like stars.
central / peripheral vision	Whatever direction we direct our eyes, we see a wide field of view, extending left and right, up and down. The central few degrees of this field, where we consider that we are "looking," is called central; the surrounding field is our "peripheral" vision. It is with our central vision that we can see the most detail, and we use it for visual tasks requiring the perception of fine detail such as reading.
cone cell	A type of light-sensitive cell, located in the human retina, that has a conical appendage containing the actual light-sensitive membranes. Cone cells are sensitive only to relatively high light levels, and are able to distinguish colors.
constellation	A group of stars traditionally identified as a group, usually named after a mythological being that they supposedly resemble in outline.
dark adaptation	The processes by which the eyes adapt to dark conditions.
glare	Light shining directly into one's eyes, and sufficiently brighter than the surrounding area to interfere with visibility and/or cause discomfort.
light pollution	Light where or when it is not wanted or needed.
light trespass	Light falling onto a property but originating from light fixtures on a different property.
rod cell	A type of light-sensitive cell, located in the human retina, that has a rod-shaped or cylindrical appendage containing the actual light-sensitive membranes. Rod cells are very sensitive to low light levels, but are not able to distinguish colors.
retina	The light-sensitive tissue of the eye, forming the innermost layer at the back of the eyeball.
sky glow	Light directed toward the ground and our eyes from the air, causing the sky to glow. This light can originate either in the air itself (often called "airglow") or from artificial lighting used on the ground (often called "light pollution").

Activity 1: Star Hunters

Objectives:

- ☆ Learn the constellations *Ursa Major* (the Big Dipper), *Ursa Minor* (the Little Dipper), and the star *Polaris* (the North Star).
- ☆ Learn how to use "averted vision" or "peripheral vision" to see faint stars
- ☆ Practice finding faint stars

Materials:

- ☆ A clear night with little or no moon in early October; it doesn't have to be perfectly clear, but you have to be able to see the stars!
- ☆ Charts 1 and 2
- ☆ A *faint* flashlight with a red filter (see box page 10).

Methods:

Step 1: On a clear, moonless evening during early October, after the sky gets dark (about 7:30pm), face North and hold Chart 1 so the "N" at its top edge is toward the bottom (the chart will be upside down). To help you orient yourself, the direction that the sun set is about west. Use the flashlight to help you see the chart if necessary. Remember, the center of this chart is the point straight over your head!

Step 2: Use Charts 1 and 2 to identify the Big Dipper, which is fairly low in the Northwest. The Big Dipper is a name for seven of the brightest stars in the constellation of *Ursa Major*, the Big Bear. If you can see the Big Dipper, use the "pointer stars" at the end of the bowl to find *Polaris*, the North Star. This star is at the end of the handle of the Little Dipper. Like the Big Dipper, the Little Dipper is part of a larger constellation, in this case *Ursa Minor*, the Little Bear. Several of the seven stars in the Little Dipper are quite a bit fainter than *Polaris* or the stars of the Big Dipper! Can you see all seven?

Step 3: Using Chart 3, look directly at each of the seven stars that form the Little Dipper, labeled from A through G, from brightest to faintest. In the table below, check off each star you can see when you look *directly at it* on the row labeled "Direct Vision" (star A is checked for you). Can you see all seven this way?

Star	A	B	C	D	E	F	G
Direct Vision	✓						
Averted Vision							

Notice that if you stare directly at a star, it tends to disappear – especially if it's faint. You will see stars better, especially fainter ones, when you do not look directly at them, but instead a tiny bit to the side. Look a little to the left, right, a little above and a little below the star – moving your eyes you can see many more stars than if you just look straight on. This is using your "peripheral vision" or "averted vision" – this type of vision is much more sensitive to faint light than your "central vision." Most people need some practice to "see things without looking right at them." On the second line in the table, labeled "Averted Vision," check off the stars you can see only using averted vision.

Step 4: (optional activities)

- Can you find some of the other constellations shown on Chart 1 or Chart 2?
- Look at this part of the sky an hour later, or two hours later. What changes can you see? Why?

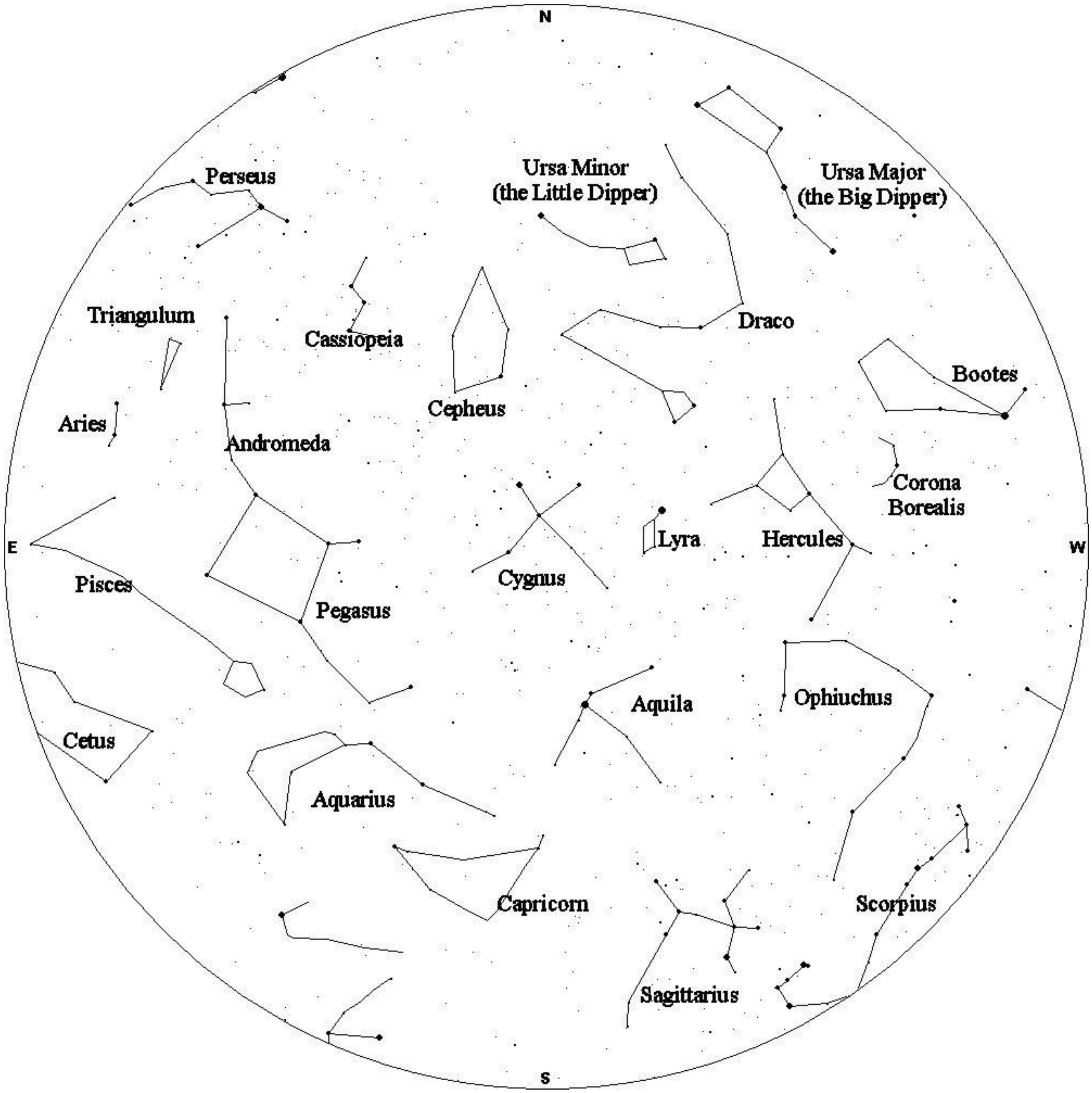


Chart 1: The October Evening Sky. This is a map of the sky as it appears looking upward. Compare the dot patterns on the map with the stars in the sky. The center of the map is the zenith (straight up) while the circle around the map represents the horizon.

Activity 2: Backyard Star Count

Objectives:

- ☆ Students will discover that the sensitivity of their eyes in dark conditions increases with time (their eyes adapt to the dark).
- ☆ Students will see that the number of stars they can see depends on how long they let their eyes adapt to the dark, and how much light pollution they have in their back yard (how bright the sky is).

Materials:

- ☆ A *clear* night with *no moon* in early October. It must be perfectly clear!
- ☆ This activity sheet
- ☆ Chart 3/Data Sheet
- ☆ A pencil
- ☆ A very faint flashlight with a red filter (see box page 10)
- ☆ A watch

Methods:

Step 1: On a clear, moonless night in early October – this night must be *really* clear – no clouds at all! – dress warmly and go outside with your Chart 3/Data Sheet after it's completely dark. Sunset is at about 6:00pm, and twilight ends by 7:30pm, so go outside at about 7:30. Find a place in your yard (or near your home if you have no yard) where you can see all of the Little Dipper. If you can, find a spot where you cannot see any bright lights: no streetlights, lighted signs, neighbors' porch lights, or brightly lighted windows on homes, including yours! Get comfortable – you might sit in a chair facing North. Protect your eyes from lights! If you see a car's headlights passing by, cover your eyes!

Step 2: Refer to your watch, and enter the time you went outside (hour and minute) on your Data Sheet. Use the flashlight as little as possible!

Step 3: Find the Little Dipper. Again, use the flashlight as little as possible!

Step 4: Beginning with *Polaris*, labeled "A" on Chart 3, locate all the lettered stars that you can see, using direct and averted vision. As you get higher up the alphabet and to the faintest stars you can see, it will take you some time with each star to decide if you can or can't see it. For the faintest star you can see, you will only see it some of the time, and only with averted vision! Take a minute or two to decide, not longer. Using the "Observation 1" table on your Data Sheet, check off all the stars you see. *It is important for the observation that you try hard to see as faint as you can, but be scientific and honest!* It is also important to use the flashlight just as little as is necessary to help you know where to look – if you use it too much it will ruin your night vision and you will see only bright stars. After you finish this first observation, enter the time (hour and minute) at the top of the Table.

Step 5: Repeat Step 4 three more times, each time about five minutes after the previous count. Check off the stars you can see on the other tables on your Data Sheet, and indicate the time that you finish each observation at top of each table.

Step 6: Go Back inside

Record your name: ______________________________________ your age: ________________

Record the street address of your home (include house number!) or the location you made the observations (example: 211 West Aspen Ave): ____

What is the name of the cross street nearest your street? ___________________________________

Record your Teacher's Name: _____________________________ and your grade: _____________

Were any bright lights visible from your observing location? ________________________________

If your answer above is yes, describe the light(s) and how far away it was (example: neighbor's porchlight, across the street): ____

____

Step 7: Using your Data Sheet, enter your data in this table, listing time, number of minutes in the dark, and number of stars counted. In the last column, convert the letter of the faintest star to the astronomical magnitude using the conversion table provided.

Time (hour:minute)	**Minutes since coming outside**	**Letter of Faintest Star Seen**	**Magnitude of Faintest Star**

Step 8: Make a graph of these data, with the number of minutes in the dark across the horizontal axis, and the magnitude of the faintest star up the vertical axis. If your observation times are not exactly at 0, 5, 10 and 15 minutes in the dark, plot the points at the proper location for your times.

Step 9: Analyze your results. Discuss these questions and any others you can think of: How many stars did you see? Did you see more at the first observation, or at the last? Why? What was happening to your eyes? Do you think you would see more stars if you waited even longer in the dark?

NOTE: The faintest star labeled on Chart 3 (P) is too faint to be seen with the naked eye. It is included as a quality check of the students' observations. Any results indicating star P is visible are likely unreliable.

Activity 2: Backyard Star Count – Chart 2

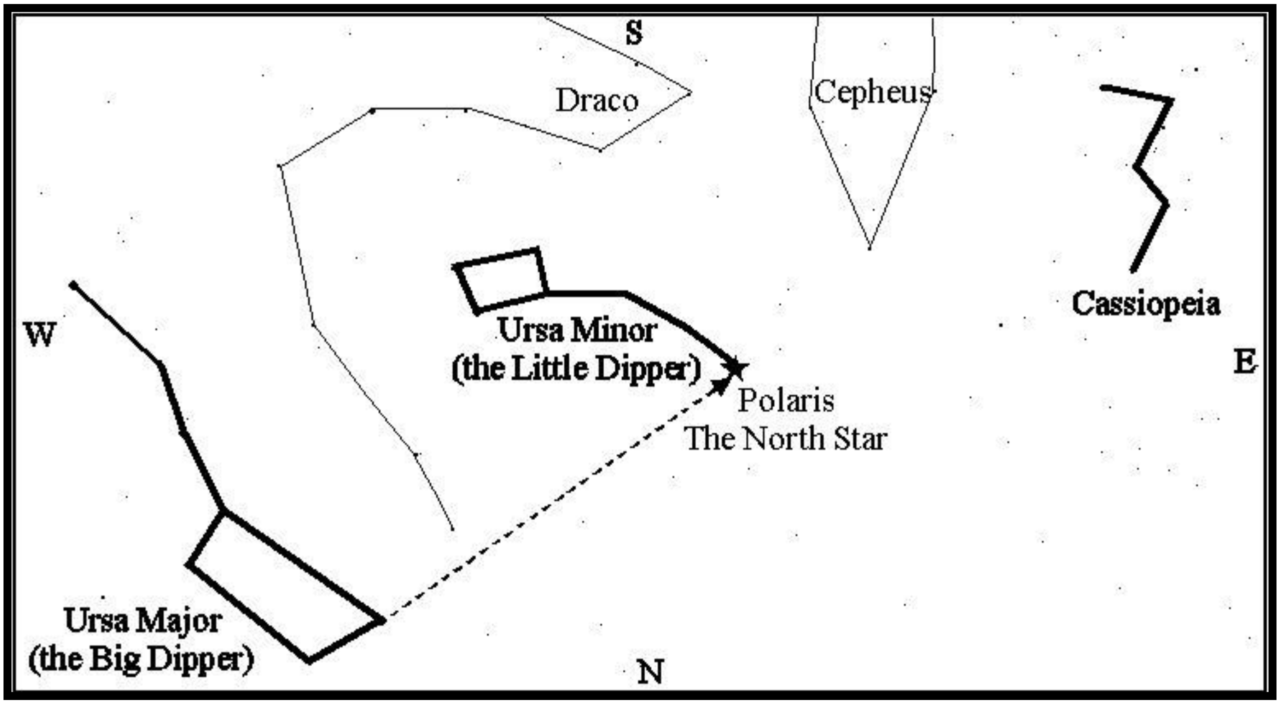


Chart 2: The Northern Sky. Facing north at 7:30pm MST in early October, the Big Dipper will be setting in the Northwest. It may be hidden by nearby buildings or trees! The "Pointer Stars" in the cup of the Big Dipper can be used to point to the North Star. The North Star can also be found by looking about halfway between the Big Dipper and Cassiopeia. Cassiopeia appears as a zigzag shape, or a "w" on its side.

Making Your Nightvision Flashlight

Materials needed:

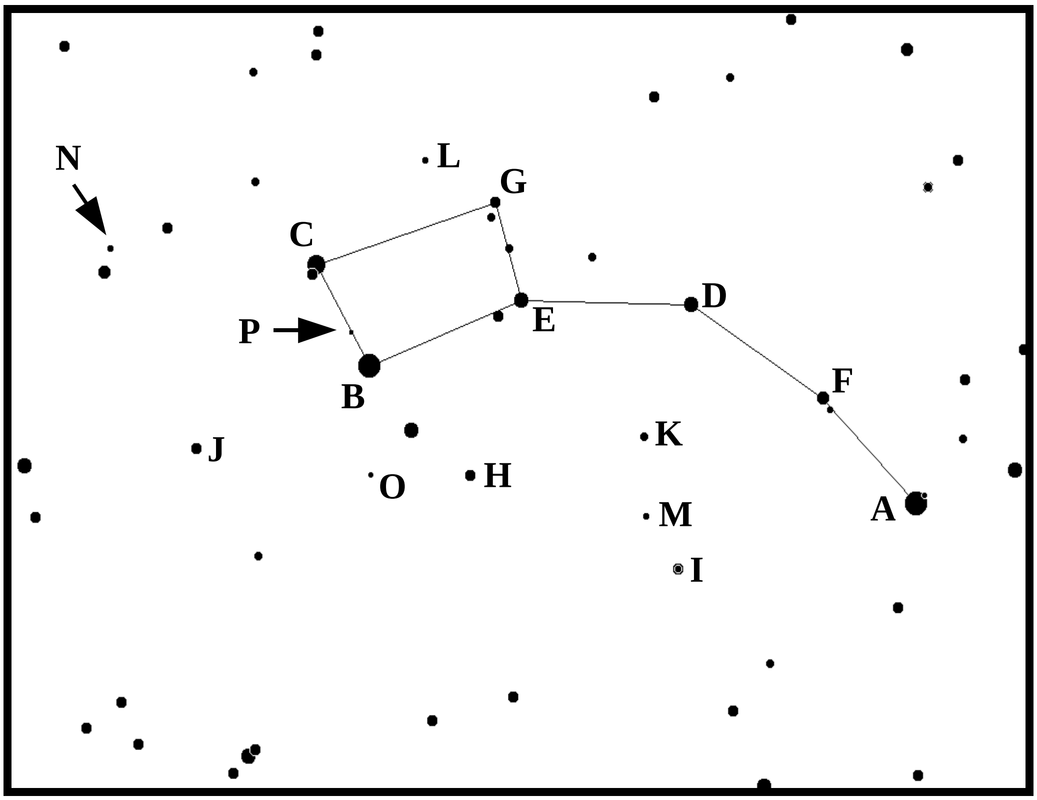
- regular flashlight – do not use a very bright one!
- piece of red cellophane about 6 x 6 inches
- piece of heavy brown paper shopping bag about 6 x 6 inches
- rubber band

Cover the flashlight lens with the red cellophane square, then the brown paper bag square. Use the rubber band to hold them in place. Use even this faint light only as much as absolutely necessary to preserve your most sensitive night vision!

Activity 2: Backyard Star Count – Chart 3/Data Sheet

Observer's Name: ____ Date: __________________

Time you came outside (hour:minute): ___________



Observation 1
Time _______

Star	Check
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	
M	
N	
O	
P	

Observation 2
Time _______

Star	Check
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	
M	
N	
O	
P	

Observation 3
Time _______

Star	Check
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	
M	
N	
O	
P	

Observation 4
Time _______

Star	Check
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	
M	
N	
O	
P	

Activity 3: Map Star Visibility for Your Class

Objectives:

- ☆ To map the visibility of stars by placing the star counts determined in Activity 2 on a map of Flagstaff.
- ☆ To compare the visibility of stars for all the students in the class, and to explore the reasons different numbers were seen by different students in different areas of Flagstaff.

Materials:

- ☆ The results of Activity 2 for each student
- ☆ A map of Flagstaff
- ☆ Colored markers or colored adhesive dots (six distinct colors such as red, orange, yellow, green, blue, purple)

Methods:

Step 1: Back in class, on a map of Flagstaff, put the letter or magnitude (to convert letters to magnitudes see Step 3) of the faintest star each student saw on their Fourth Count onto the map at the location of his or her home. Optional: put the letter or magnitude on a colored dot, following the color scheme below, then stick the dot onto the map.

Step 2: Circle each letter or magnitude marked on the map with a colored marker as follows:

Letter of Faintest Star Seen	Limiting Magnitude	Color
A-C	1.0-3.0	red
D-F	3.1-4.5	orange
G	4.6-5.0	yellow
H-J	5.1-5.5	green
K-L	5.6-6.0	blue
M-P	6.1 or greater	purple

Step 3: (optional) Use the Limiting Magnitude Conversion table to convert your star letters to astronomical limiting magnitudes.

Step 4: Discuss the following questions.

- ☆ Do you see any patterns on the map? Are there areas where most observers saw fewer stars (red, orange, yellow), and others where more were visible (green, blue and purple)?
- ☆ Where could students see the most stars? Where the least?
- ☆ Why? Are areas where few stars were visible located near brightly lighted areas of the city?
- ☆ If one observer saw a much different number of stars than other observers located nearby, what could explain the difference?
- ☆ How does light get into the night sky from outdoor lights like streetlights or porchlights?
- ☆ Would it be possible to reduce the amount of light getting into the sky? How?
- ☆ To reduce light in the sky is it necessary to reduce the amount of light on the ground where it is needed?
- ☆ Is it important to you to be able to see stars? Why?

Limiting magnitude conversion – Ursa Minor

Using this table, we can convert the letter of the faintest star seen in Activity 2 to the astronomical *limiting magnitude* (**Lm**). The system of magnitudes is based on the ancient system devised originally by the Greeks to rank the stars by brightness: first magnitude stars are the brightest, and sixth are the faintest visible to the eye. Today astronomers have precisely quantified this old system, and magnitudes for stars can be determined to one-hundredth of a magnitude or even more precisely. We now know that good observers in unusually good sky conditions can see even fainter than the sixth magnitude. How faint did you see?

Letter	Lm
A	2.1
B	2.4
C	3.0
D	4.3
E	4.4
F	4.4
G	5.0
H	5.1
I	5.3
J	5.5
K	5.8
L	6.0
M	6.1
N	6.3
O	6.5
P	8.7