My Excellent Adventures at Astronomy Camp

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University of Arizona Astronomy Camp
Class of October 8-10, 2010
Trip Report presented to
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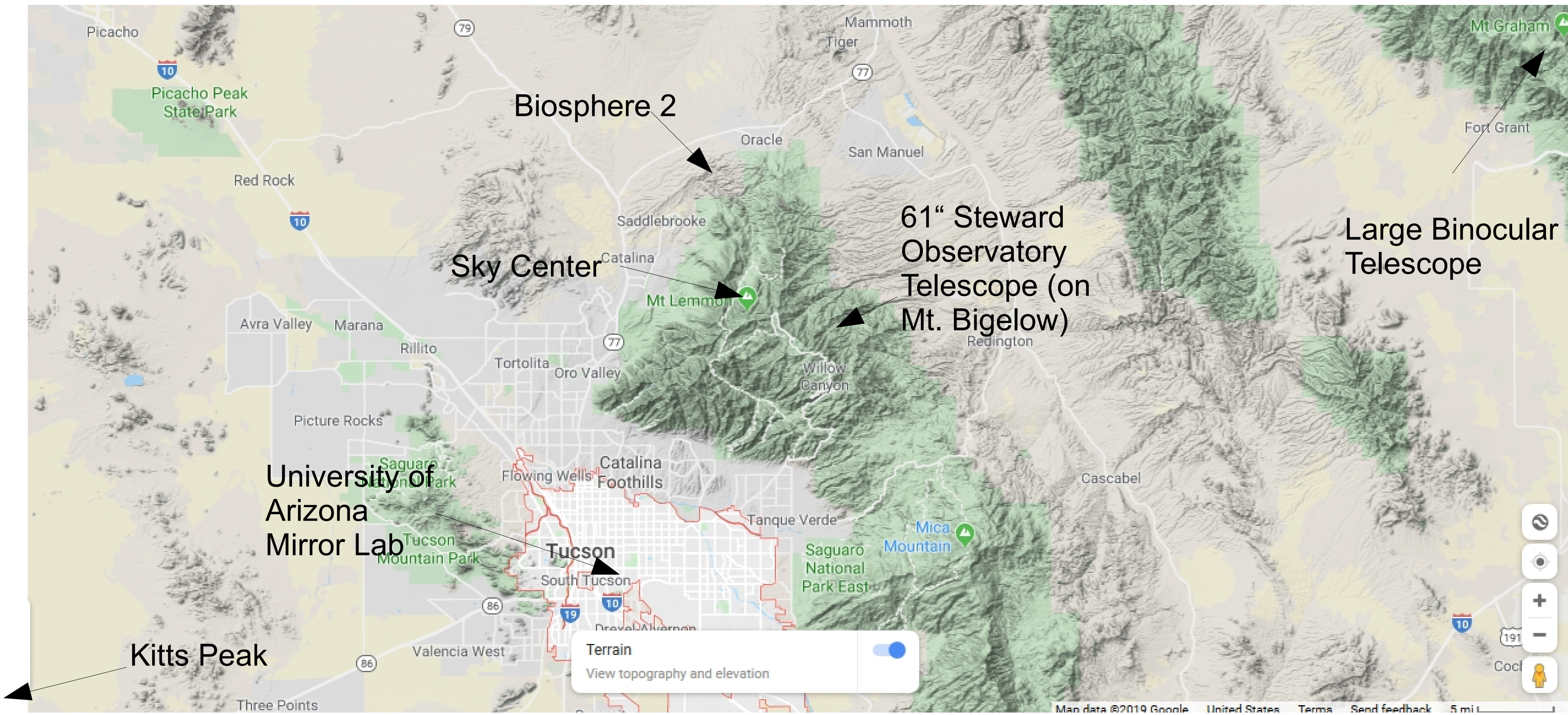
Image: Glenn Holliday



Girl Scouting sent me to Arizona's astronomy wonderland to learn how to do astronomy with Girl Scouts. The University of Arizona has done Astronomy Camp for many years, for both youth and adults. My 3 day program was mostly at the University of Arizona's Sky Center on Mount Lemmon. The week long programs sometimes include a field trip to fabled Kitts Peak.


University of Arizona Sky Center,
Mount Lemmon
Image: Glenn Holliday

Dr. Don McCarthy, director of the Astronomy Camp program.

Dr. McCarthy is responsible for several firsts in infrared astronomy. His big interest, and goal for Astronomy Camp, is igniting passion for science in our youth. That's something he is good at.

The first time I used this long, red-lit entrance hall to the men's dormitory, I thought its purpose was to begin adapting my eyes to the dark as I left the building. There are no white lights outdoors here, and a sign on the entrance gate says "No headlights".

I learned it was built for a different purpose. They found they could not keep the dorm clear of snow during the winter, so this hallway extends the door to the road, where the snowplow can reach. Though the base of Mount Lemmon is desert, they get 200 inches of snow each winter up here on the peak.

Image: Glenn Holliday

And this building keeps its door free of snow by putting the door on the second floor.

This is the Army Tower. Mount Lemmon was at one time part of the continental defense system. The dome of this tower housed a radar. It is now empty (though the University of Arizona has considered converting it to a telescope dome).

We had most of our class work and meals in this building.

Looking east from the mountaintop telescope domes on Mount Lemmon, we could see the Large Binocular Telescope on Mount Graham. In this picture, it's the tiny white rectangle on the second ridge.

Astronomy Camp comes in flavors

- Week long program for high school youth
  - Beginner and Advanced
- Week long program for adults
  - Beginner and Advanced
- Weekend program for Girl Scout leaders

Many campers went on to become astronomers and academics.
One is the Lead Flight Director for the Space Shuttle program.

The fabled Arizona sky

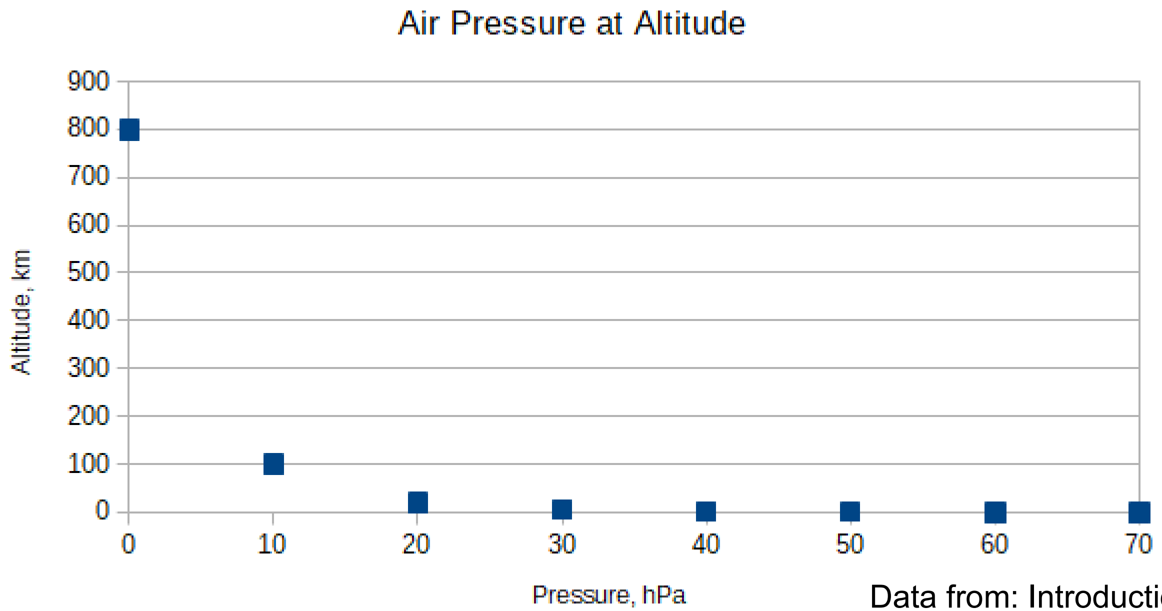
King George
October afternoon

Mount Lemmon
October afternoon

The top of Mount Lemmon is at approximately 9200 feet (approximately 2800 meters). There is much less air above this altitude, so the air scatters sunlight less than it does at lower altitudes. This often gives the sky a deeper blue appearance. This same phenomenon increases with higher altitude, so that at the edge of space, the sky appears black.

This is also high enough to cause altitude sickness. We have no place here in the East that high. I was pleased that I did not have any trouble with the altitude, thoroughly enjoyed the mountains, and would love to spend some days hiking and camping there. I found that walking uphill any distance at all left me winded.

Having less air above us also meant there was less protection from the sunlight. You can tell the people who live here - they wear sunhats any time they go outdoors.



Data from: Introduction to Atmospheric Chemistry

At sea level, 100 miles of air are pushing down on the air that's next to the Earth. That packs it down more densely. Denser air contains more air molecules, so it has more mass. That also makes it higher pressure. Air pressure and density decrease logarithmically with higher altitude. So as you go up a little bit in altitude, you get a greater decrease in air pressure. There is much less air over your head.

So how dark was it?

Arizona has a reputation as the best sky in the United States for astronomy. I was on top of a mountain taller than any altitude in the East, so I had a lot less air to look through. I went to Arizona very excited about seeing its fabled night sky.

The sky atop Mount Lemmon was darker than the sky at home, but I didn't find the dramatic difference I expected. I could see some dimmer objects than I can at home.

- I could see M31 (the Great Andromeda Galaxy) with my unaided eyes. At home that requires binoculars.
- Some people at camp with me reported seeing M33 (the Triangulum Galaxy) unaided. I could not. It is a little dimmer than M31.
- The Mount Lemmon sky was better than the places at which Rappahannock Astronomy Club has star parties, but only a little better.

Why wasn't it darker?

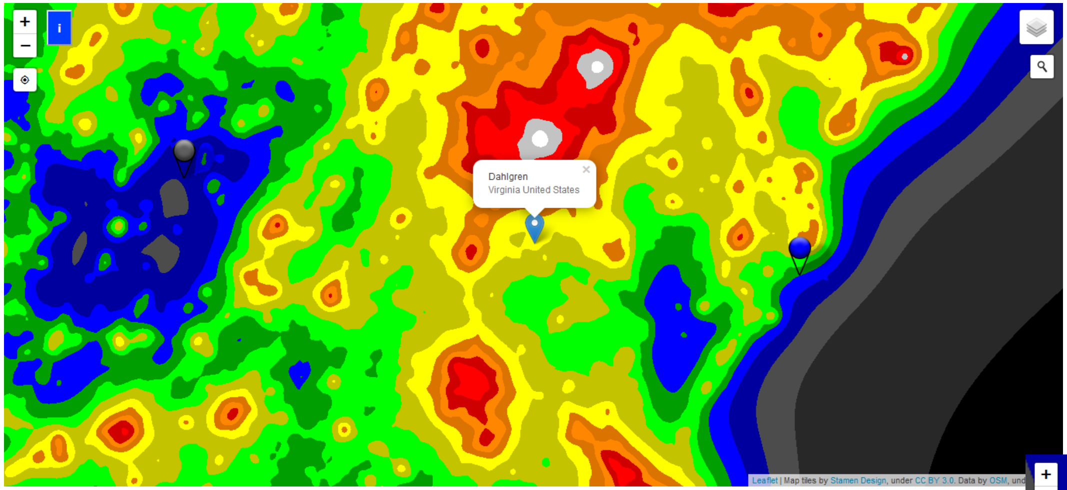


Image: Dark Site Finder

The sky did not appear darker because of light pollution. These maps show the amount of light pollution in my home in Virginia, and in the area around Mount Lemmon where I was at Astronomy Camp. The two locations are at approximately the same point (class 4) on the Bortle scale.

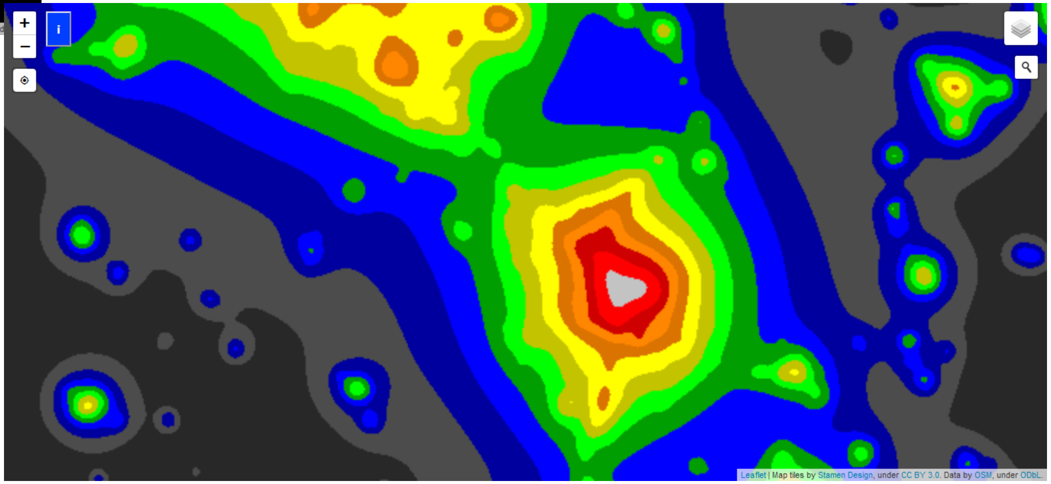


Image: Dark Site Finder

From the mountain top, we could see the lights of Phoenix to the northwest and the lights of Tucson to the southwest. We were much closer to Tuscon, but because that city has ordinances encouraging lighting that preserves dark sky, we saw much more light coming from Phoenix.

Just to the left of Tuscon on the Arizona map is Kitts Peak. Note that it has a much darker sky. However, the boundary between dark sky and polluted sky is only a few miles from Kitts Peak. The National Observatory there is trying very hard to keep that boundary from moving any closer to their telescopes.

Each day started with observing the pre-dawn sky at 4:30, then we observed the sunrise, had class all day, and ended with observing the stars till after midnight. Daytime highs were near 90° F, nighttime lows were near 30° F.

All of it was incredibly fun.

Every evening we observed the night sky, using the type of hobbyist equipment that any Girl Scout troop might have available. This Dobsonian telescope was made by students at a Tucson high school. We had Galileoscopes and binoculars. Later in this report we also spent some time on larger equipment.

You can recognize that the temperature is dropping by the attire. A Girl Scout cookies sweatshirt may be an essential item for Girl Scout astronomy.

This is a 21 inch reflector in one of the domes at the Sky Center. I enjoyed comparing the views in this telescope to the views we had of the same objects in the smaller instruments. I had tracked Comet Hartley 2 earlier in the evening in the Dobsonian, and could see no detail beyond a fuzzball. In the 21 inch professional instrument, we could distinguish different brightnesses in the structure of the comet.

In the dome next to this one, a group of astronomers was searching for near Earth objects - making a list of asteroids and comets that might endanger the Earth.


Image: Glenn Holliday

One thing we observed together each day was sunset. The sun's green flash is observable from here. From the top of the Army tower we were at a higher elevation than the horizon behind which the sun sets (this is one of the physical requirements to see a green flash). I saw the phenomenon, though I failed to capture an image of it. Shortly after I took this image, the upper rim of the sun dropped behind the trees on the far western ridge. I could see trees in front of the rim. As the sun disappeared behind the ridge, I saw its orange color turn green for just a moment.

Then, just after sunset, we looked back to the east to see a different phenomenon. In this image the shadow of the western horizon falls on the eastern sky and darkens it. The sun is now below the western horizon, but its light travels in a straight line across the edge of the earth, illuminating the sky at a higher altitude, above the line of shadow. This line is where an observer at that altitude would see the sun setting

The Kuiper Scope on Mount Bigelow


Image: Glenn Holliday

This is a reflecting telescope with a 61 inch mirror, built as part of the Apollo program in the 1960s. Gerard Kuiper used this telescope to map the moon and select landing sites for the Apollo missions. Kuiper was the founder of the Lunar and Planetary Laboratory at the University of Arizona, and is best known for predicting the existence of the Kuiper Belt in our solar system.

This telescope is huge. It is usually used to record images for later analysis, so it is unusual to have a group like ours put an eyepiece into it and stand underneath it for visual observing. The floor in the chained-off area underneath the telescope moves up and down to match the height of each person observing. It felt a little confining to put my head right up against tons of metal, but that feeling was quickly overwhelmed by the awe and beauty of the views through this instrument.

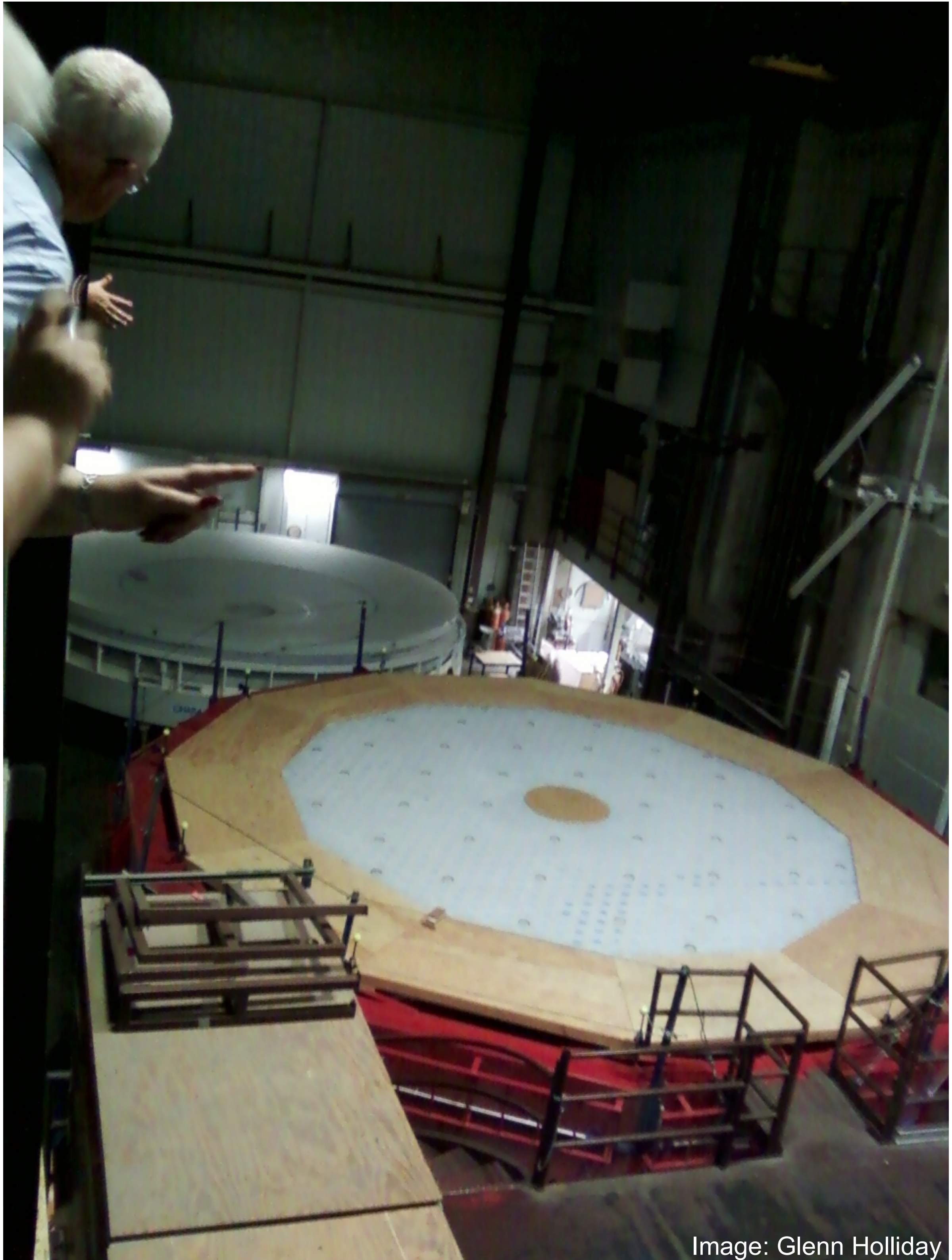
What can you see with a 61 inch mirror?

- Colors in planetary nebulae. In amateur scopes you see very few colors - most nebulae appear gray. It was a thrill to see pastel pinks, greens, and purples.
- I exclaimed "I can see the disks of the moons of Jupiter!" Jupiter's four largest moons are bright enough to be visible in any binoculars, but they are so small that they always appear as points of light, as do stars. Dr. McCarthy replied calmly "That means we're getting arcsecond resolution. That's good."
- White dwarfs. Most stars that form a planetary nebula evolve into a dim white dwarf. These are very difficult to see in amateur scopes. We were able to see the dwarf at the center of every planetary nebula we looked at.
- Stars in globular clusters. These objects are distant balls of, often, hundreds of thousands of stars. I'm used to being able to resolve a few stars on the edges of the closest ones, with most of the cluster a dense snowball of stars. In this instrument, I could resolve individual stars in the centers of the globular clusters we looked at.
- Huge magnification. We were looking at approximately two arcminutes of the sky. That's too small to see Jupiter and its moons all in the same field of view - I was panning the telescope between the planet and the moons. I have never seen such a high magnification in any other telescope.

In the hobby, we commonly express magnification as powers of magnification. 10x means that an object appears 10 times closer, and we see 1/10 as much sky as we do with the unaided eye. The professional astronomers at camp told me "We don't use that." Converting the pro expression "two arcminutes" to a familiar hobbist magnification requires knowing some numbers about the telescope and eyepiece that I did not ask for, but we were seeing something above 1000x. And getting great seeing and a nice steady image.

Steward Observatory Mirror Lab

This glass furnace makes a 8.5m mirror, the largest in the world.
Currently making 7 of them for the Giant Magellan Telescope, Chile



Here are two of the cast mirrors waiting their turn to be polished. This facility is underneath the University of Arizona football stadium. The floor has an independent suspension so vibrations from the stadium are not felt by the mirrors or equipment here.

You can see the far mirror is not solid all the way through. A later image will show a detail view.

Image: Glenn Holliday

Telescope mirrors are curved in order to focus incoming starlight to a single point. The furnace slowly rotates, so that centrifugal force forms a meniscus in the molten glass, giving it an initial curved shape as it cools to a solid. Then the mirror need to be ground and polished to the exact shape required.

The machine on the left automatically grinds and polishes one of these large mirrors at a time. A computer records the desired shape. After passing through the machine, the mirror moves to a second measuring machine. The mirror in this image is being measured after leaving the polishing machine. The long arm is bouncing lasers off many points on the surface of the mirror. Measuring the time for the pulses to return gives the precise distance to each measured point. This lets the machine compute the actual shape of the mirror, and compare it to the desired shape.

This process produces a mirror accurate to within 4 nanometers of the desired shape. We were all impressed by that number until Dr. McCarthy told us you can get approximately the same accuracy when you polish a mirror by hand. The difference is you could not polish such a large mirror by hand.

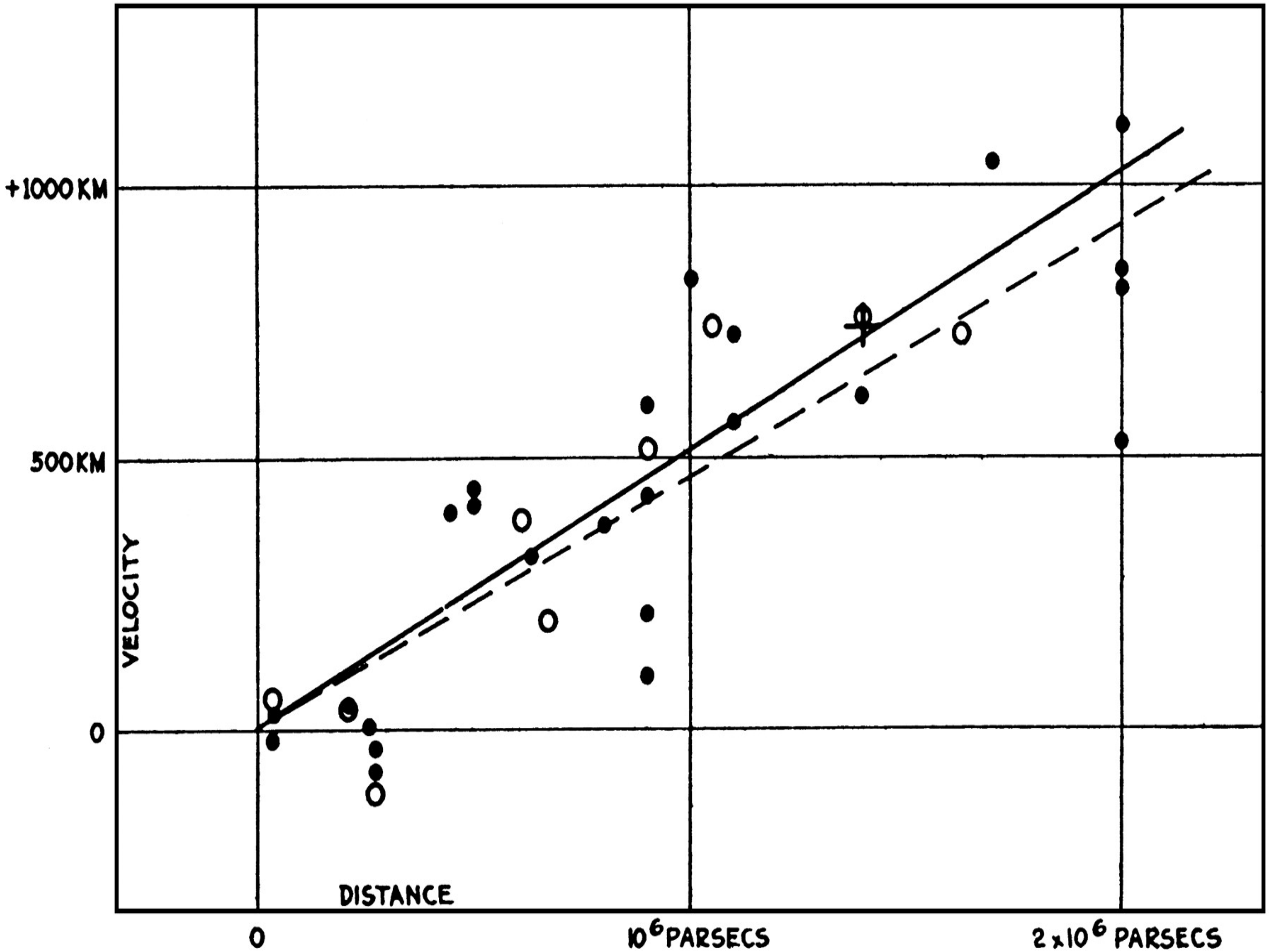
This is a piece of one of the mirrors made at the Steward lab. The furnace casts this honeycomb shape for two reasons:

- The mirror is lighter than a solid slab of glass of the same size. This makes it easier to handle.
- The honeycomb is a very strong pattern.

James Webb Space Telescope

Image: NASA

This is the reason I got to go to camp.



We want to see things older and more distant than we have seen so far.
Visible light telescopes can't see them because their light has redshifted into the infrared.

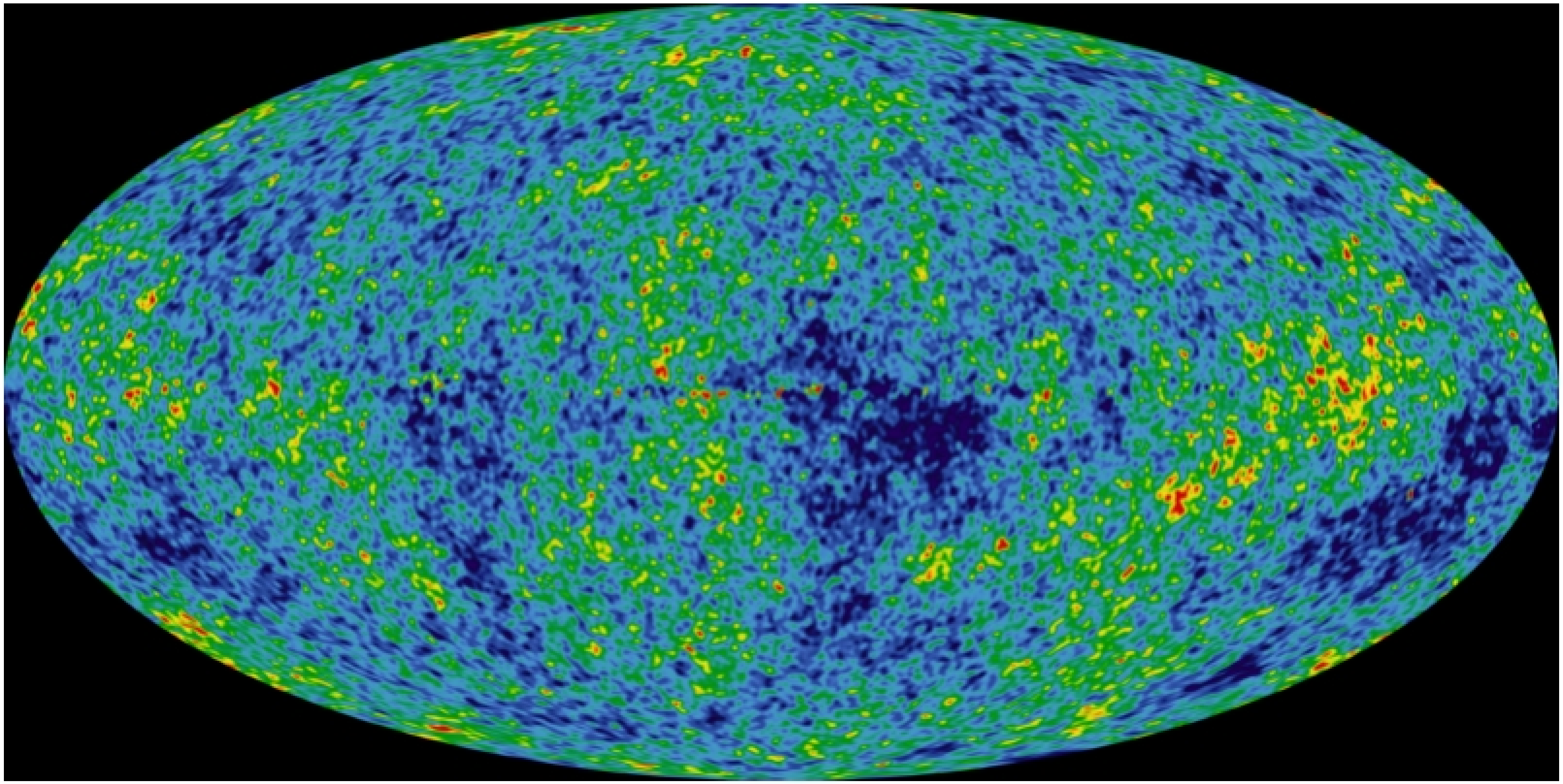


Image: NASA

The most distant light has redshifted into the microwave.

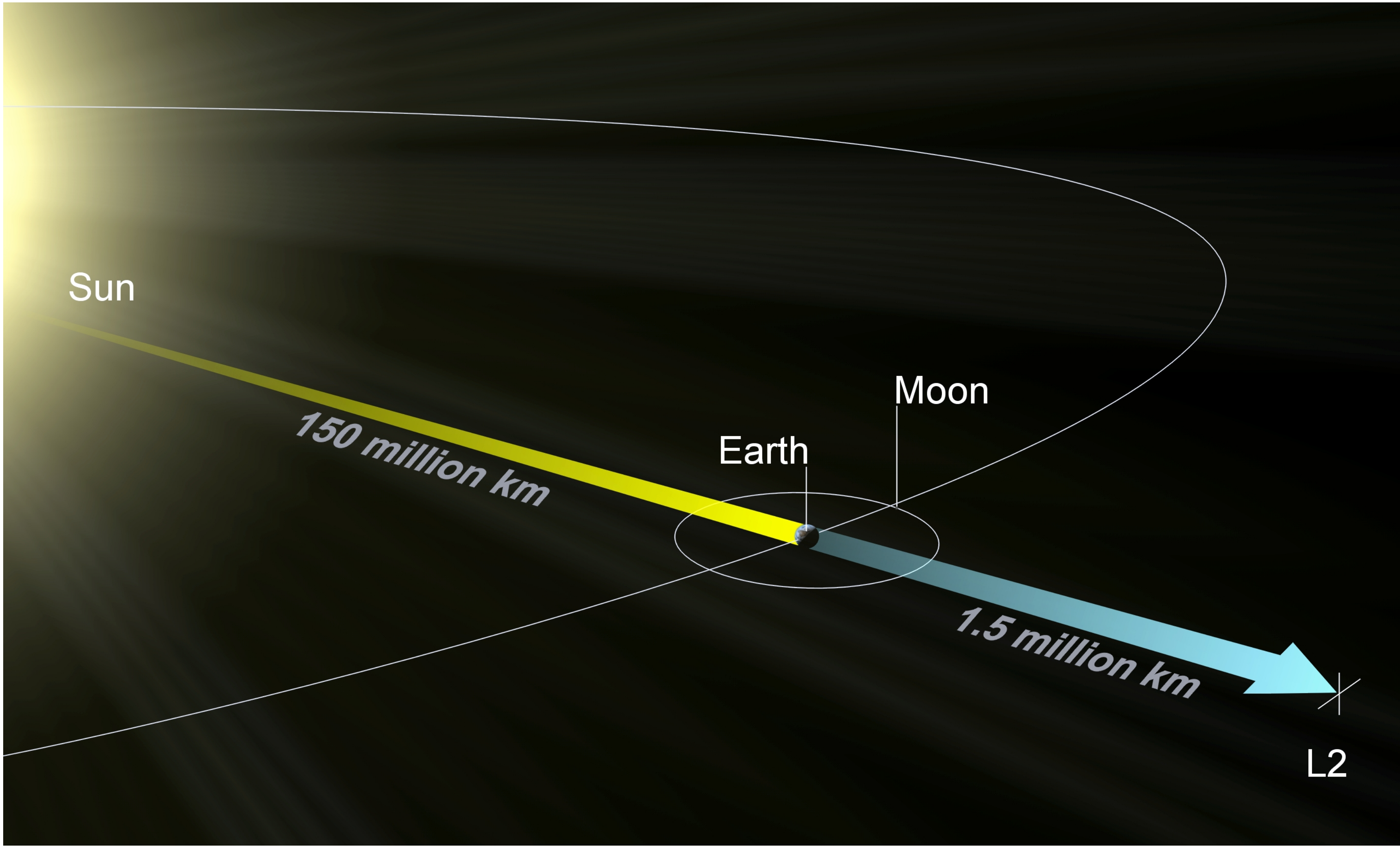


Image: ESA/Hubble

JWST will not orbit Earth, but one of the Lagrangian points

Image: NASA

This NASA photo shows the assembly of the two main cameras of the James Webb Space Telescope. The University of Arizona is the science team for the Near Infrared Camera
The interesting part here is that the light entering the telescope has to go in two directions in order to be used by two different instruments. Since the incoming starlight is very faint, you don't want to lose any of it getting absorbed by mirrors and lenses.


Image: Glenn Holliday

This image shows the solution used in the James Webb Space Telescope. Dr. McCarthy is holding an example of a dichroic material that naturally reflects and transmits different wavelengths of light. You can see that the mirror in his hand is reflecting light that is falling onto it, but you can also see that it transmits green light to fall onto the screen behind. No material is a perfect reflector or transmitter, so some energy is absorbed and lost, but this is the engineering solution that lets the most light possible get to the cameras.

The mirror Dr. McCarthy is holding is a broken fragment. He described it as "a $50,000 mistake."

This image also illustrates the infrared bandwidth that the James Webb Space Telescope will see. We are projecting a signal from an infrared camera onto the screen.

Image: Glenn Holliday

Another important characteristic of the James Webb Space Telescope is that it will be very cold. The telescope will operate at approximately 40 Kelvin. This presents challenges that very few machines have to face. (It is one of the reasons the telescope has required more time and money to build than first budgeted.)

To learn about what you can do at very cold temperatures, we did an afternoon of experiments with liquid nitrogen. This image is of the most important experiment, which taught us that you can make really, really good ice cream by flash-freezing it with liquid nitrogen.

Doing Astronomy With Youth

Image: Kaptain Kobold


Image: Glenn Holliday

A huge part of doing astronomy with youth is observing the night sky. A second large part is helping youth to discover the more important facts and relationships astronomy has discovered about objects in the universe.

Learning, especially with young people, often happens best with immediate, physical manipulation of the world. We experimented with many models of the universe. This image is a camper using one model of the volume of our solar system. Start with a lump of dough and divide it into lumps corresponding to the volumes of the planets of our solar system. The result immediately make clear what planets are similar and the scale of the differences between the gas giants and the rocky planets.

Image: Glenn Holliday

This is a model of our nearest neighbor stars. This one gives a number of Scouts an opportunity to be active. It shows several characteristics: distance from us, geometric arrangement (you can make it an accurate three dimensional model if you have ways to place people at different heights), size and color of the stars, and also their life cycle. We ran a timer and burst the balloons after times corresponding to the expected lifetime of each star.

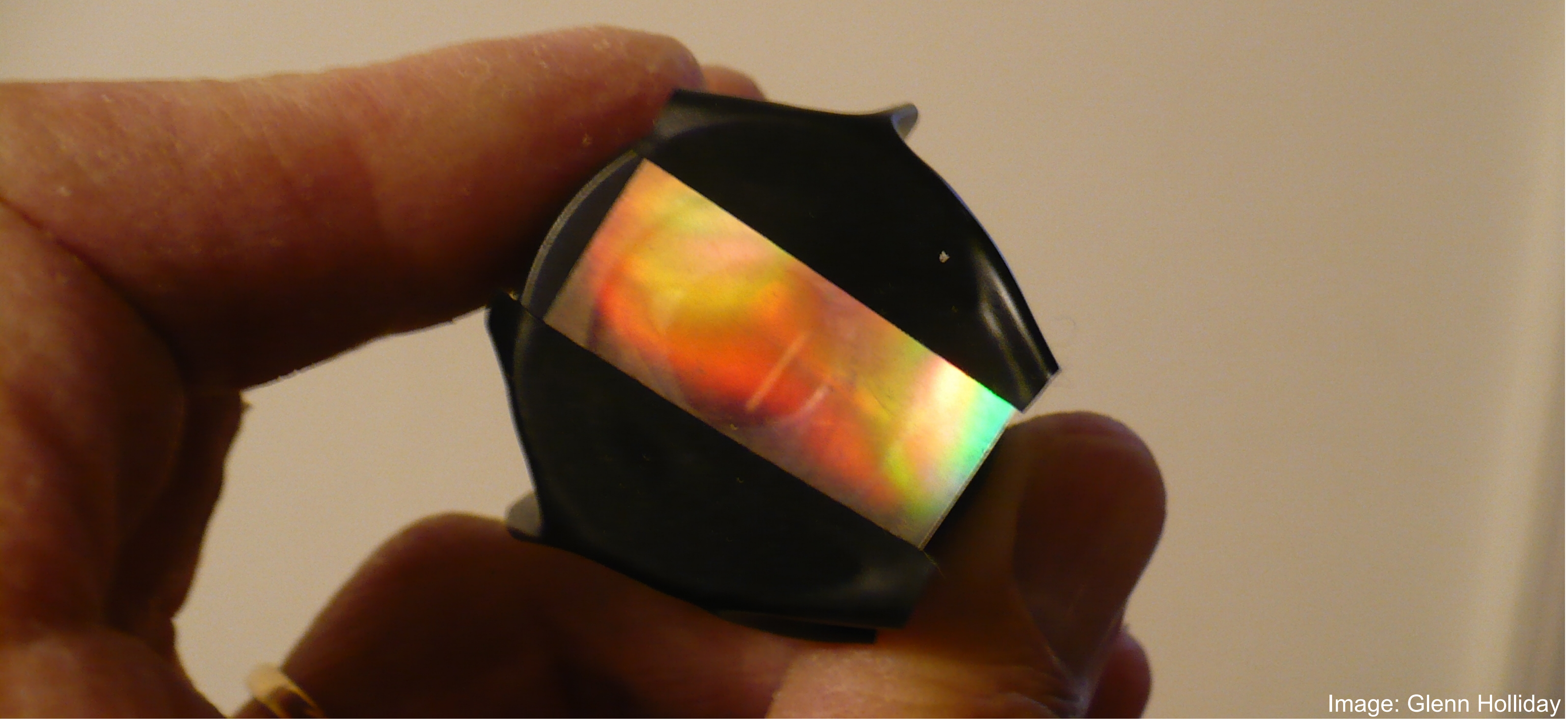


Image: Glenn Holliday

We built a spectroscope. Astronomy gathers data in several ways. Most people are familiar with observing the stars and taking pictures of them. Visual observing tells us a lot about what is out their and the geometric relationships between objects. Another fundamental activity is spectroscopy, which tells us what luminous objects are made of. Redshift was discovered through spectroscopy, and it also gives us information about the speed of objects. A third fundamental activity is photometry, or measuring the amount of energy arriving from astronomical objects.

You can build scientific instruments to explore each of these ways to gather data. For visual observing you have telescopes and cameras. We built this spectroscope from a piece of diffraction grating. You can build a photometer from a discarded digital camera. That one may be best suited for older students with an interest in electronics.

Here is another model that gets everybody up and moving around. The class is reading cards that list data we know about stars (distance from us, mass, temperature, etc.). We sorted ourselves according to one characteristic at a time. This is a physical way to discover several things:


Image: Glenn Holliday

- Individual facts and collections of facts. It is often exciting to discover how different other parts of the universe are from our own home.
- How these characteristics influence and connect to each other. This model makes it easy to discover that a star's mass, temperature, color, brightness, and lifetime influence each other. But some things, like distance from Earth, have nothing to do with other characteristics.
- This model is an example of classification. We place stars in categories by their mass and temperature. Classification is important to all science because it is the first way to start playing with data and trying to discover if one thing causes another. So this teaches a fundamental skill that a Scout can apply when doing any kind of science.

We built a similar model of planets, and used them to compare the planets of our own star to the planets of other stars. You could use this same idea with other sciences.

This is a simple physical model of phases. The most familiar phases are those of our moon, but this model can also show why planets can have phases. Dr. Lebofsky is holding a simple sphere in the setting sunlight. We could immediately see how the sun shining from that direction causes the same phase on the styrofoam ball and on the moon, which was in the sky above Dr. Lebofsky's head. Scouts walking in the shape of an orbit can discover how simple geometry causes the other phases.

I have photos here for only a sampling of many activities and models we experimented with. I expect to use these and many more with Scout groups and other interested groups in the near future.

Bibliography and Credits

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