Earthworks 2006

Astronomy and Earth Science

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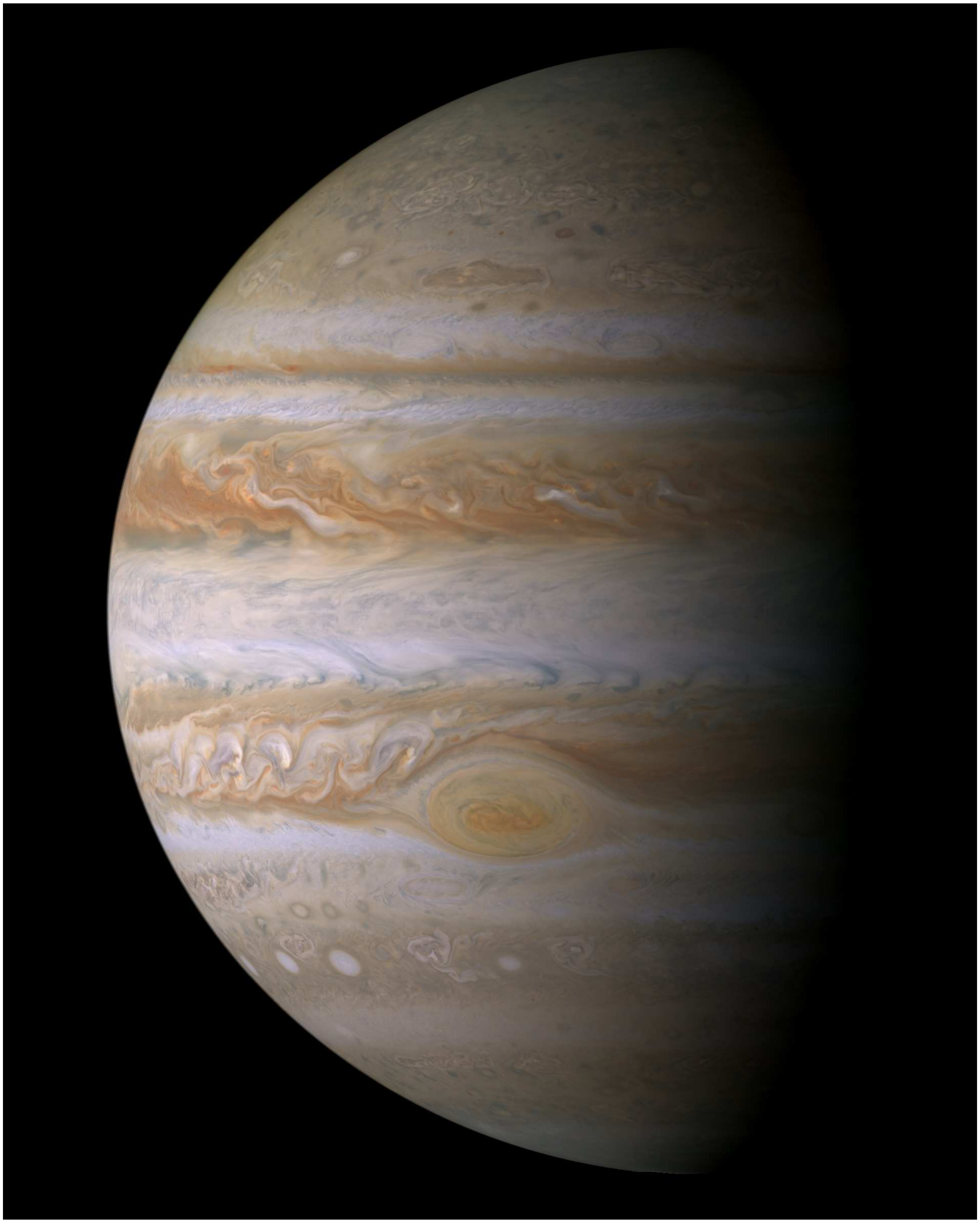

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Background
I have been doing freelance science education outreach since 2000, primarily Rainy Night Astronomy with 5th-7th grade students. (Also science fairs since 1995 come to think of it.) At the same time, as it happens, my professional career is ever so gradually heading in the direction of earth science education. In addition to presenting some Astronomy material at Earthworks this year, I describe below two subsequent propositions for collaboration with interested teachers. The first is a continuation on Astronomy and the second concerns Earth Science.

Earthworks 2006
I will present some ideas on the subject of Astronomy in the Inquiry learning model—'Astro-Inquiry'—as well as on Astronomy as a nexus for multidisciplinary education and critical thinking. Astro-Inquiry I've broken into six subdivisions: Research, Tabletop, Modeling, Programs, Observation, and Artifice. These and related ideas are written up in this pamphlet.

After Earthworks
Proposition 1: Astronomy. I would like to find teachers in the Denver—to—Ft.Collins area who would be interested in working with me on a week-long classroom astronomy unit. The general idea is to integrate subject matter with an existing curriculum and to provide students a jump-off point into astronomy. This work could optionally be facilitated by Project Astro as sponsored by the Space Science Institute in Boulder.

Proposition 2: Earth Science. I am working with other geophysicists and with my company (Microsoft) to provide earth science education resources, particularly real-time streaming data and an interpretive interface, from watersheds and marine environments in the vicinity of Juneau Alaska. The objective is to provide students an immersive experience of an ecosystem that leads to a sense of understanding of and responsibility to the environment. I would like to find teachers interested in collaborating on this project, currently in its beginning stages.

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Contents of this pamphlet

Introduction: Some Personal Philosophy

In my contact with students over the past twelve years I've come to some basic and possibly incorrect conclusions, both when it comes to teaching astronomy and when it comes to the general challenge of getting kids in motion. Here are some highlights:

- With students the first task is getting them engaged in the moment.
- Many/most of the forces within a student's personal universe conspire to prevent them from getting engaged. Popular media is often a lead culprit.
- The internet is at best (principally) a source of useful but shallow information.
- Books are infinitely better than the internet.
- Teachers are agents by which a student can become engaged.
- Basic tricks / facets in my talking with kids about astronomy:
    - Before talking, ask students what they think about astronomy.
    - Before talking, ask them if they have questions about astronomy.
    - Validate all questions even when they concern Obi Wan Kenobi.
    - It is acceptable to play sneaky rhetorical tricks on students…
        - …provided motivations and results come clean in the end.
    - It is acceptable to tell students vile and reprehensible lies…
        - …provided the lies are sufficiently outrageous…
        - …and provided they are subsequently amended.
    - Students may or may not be open to learning the Universe song…
        - …but if they *are* it is best to use the word "folderol" in the last line.
    - Science teachers should know the Universe song whether or not they teach it.
    - Astronomy contains in its foundations an astonishing guess about the nature of human existence, the 'star stuff hypothesis'…
        - The reasoning behind it I call the First Fundamental Lesson of Astronomy.
    - Astronomy is an accessible subject… sorta.
        - The moon and planets and stars are visible by eye, not to mention the galaxy in Andromeda. Much more is visible through binoculars.
            - Corollary: Don't worry about telescopes.
        - But truth be told: Astronomy as "data source" requires some ingenuity.
            - See the story of the 7th grader with a star database…
    - Astronomy gives us (let's say) Five Fundamental Lessons
        - The first is the Star Stuff hypothesis as noted.
        - The Second Fundamental Lesson of Astronomy is the Island Universe.
        - The Third Fundamental Lesson is the Incompetent Projectionist Story.
        - Fourth Lesson: Michael Crichton's Misunderstanding.
        - Fifth Lesson: The Garden of Live Flowers.

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    - These increasingly whimsical titles are expanded below.
- Astronomy is a crossroads subject.
    - It connects with physics, chemistry, and biology.
    - It connects with the subject of geological time.
    - It connects with history and culture, thereby art and music.
    - It connects all human civilizations.
    - It connects trivially with planetary science and thereby with earth science.
- Astronomy is a great context for critical thinking.
    - Astronomy has made most of its progress in the past two centuries. It has walked hand in hand with the explosions in all of the physical sciences.
    - It provides an excellent basis for "*understanding that we are capable of understanding"*.
    - The question "Does this sound reasonable?" can be investigated using only a few core ideas and physical constants.

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"You can't drill a hole in a star."

Astro-Inquiry

Take a set of tree cores and correlate the ring widths to temperature and rainfall records for the past 20 years. That is a challenging and interesting inquiry project (as I understand the term) that puts the investigator in direct physical contact with the subject matter. What about Astronomy? Alas we live out of direct contact with other worlds, excepting twelve human beings. We're obliged to take whatever information comes to us from our sun, the moon, the planets, nearby stars, and the cosmos by fortune and circumstance and the occasional robot. In thinking about this I realized that this does not class Astronomy out of Inquiry-based learning; it just necessitates adopting a little additional latitude.

- Research: All of the following demand some pawing through books.
- Tabletop: Turn ideas from astronomy into small-scale experiments.
  Do *not* try to build a thermonuclear reactor in your classroom; it wastes your time and annoys the hydrogen.
- Modeling: Physical or computational, models are great fun.
- Programs: NASA wants you to task the Mars Orbiter.
- Observing: Can you find Dark Matter around Jupiter with a pair of binoculars?
- Artifice: Take a traditional lesson and build it in Inquiry format. ***RedShift!***

Diving In

Rather than expand on these AstroInquiry ideas formally I thought it would be fun to jot down some examples of getting one's hands dirty. Here are ideas for Astro-Inquiry with Latitude.

Research

There is an increasing pool of excellent books written for the lay-person covering various aspects of Astronomy and Planetary Science. My personal favorite at the moment is Timothy Ferris' Coming of Age in the Milky Way—and from a good starting point one can bootstrap into the cosmos. I use also use the internet for two related things: I surf around Amazon making liberal use of their "Readers who liked this book also enjoyed…" feature to find good book titles. I also occasionally surf Wikipedia for the general (shallow) picture on a given topic. Magazines such as *Astronomy* or *Sky&Telescope* are also fun and have a lot of emphasis on visuals, but while being current they are also light on content and heavy on advertising. There are a few more book titles given below.

Tabletop

How much energy does the sun burn per second? It ought to be possible to roughly determine this with a solar panel, a meter and a light bulb. The solar wind is reported to be a flow of subatomic particles… if so I ask: Can subatomic particles be observed—visually observed—for under $50 on a table top? (Search on "Wilson Diffusion Cloud Chamber".) An extra CD-ROM can be converted into a decent spectroscope to get at the fingerprints of the sun. A comet can be built in a mixing bowl. In summary, short of building a thermonuclear generator, tabletop Astro-Inquiry is very accessible.

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Modeling
Whether on a computer or using a physical system, the tabletop idea can be extended to include models. I use classrooms of 5th graders to model interstellar hydrogen, planetary systems, constellations, and Greek mythology—they don't seem to mind—and the upshot is always that something unexpected tends to follow, once we go to the trouble to build something, wind it up, and let it go.

Programs
NASA wants teachers and students to tell them where to take pictures on the surface of Mars. (The pictures come back hot off the telemetry link to your classroom.) This program is one example of how the science community is supporting secondary and undergraduate science education. What's needed is the time to look around for these opportunities.

Observing
Learning the names, histories, distances, and types of bright stars is a challenging form of inquiry. Like research (above) there is no direct hypothesis testing, at least not without some sophisticated equipment. However one could still try and determine the relative periods of the four big Jovian satellites, and one could estimate the light curve of Algol in the constellation Perseus with nothing more than a pair of binoculars. In fact binoculars can (hypothetically—I haven't tried it yet(see description below)) be used to trace sunspots, another type of observing. Perhaps to Aristotle's chagrin, there are things that change in the heavens on timescales we can observe.

Artifice
This is the "suspension of disbelief" idea where an instructor formats a traditional lesson to an inquiry approach. Key information or data is provided by artificial means and the challenge is to discover it and synthesize a conclusion. I can cite the lesson on ***Redshift*** as a successful example.

I'll reiterate: If you are interested in discussing these things further with me, don't hesitate to get in touch. My email is rob@robfatland.net and that's also my website: robfatland.net. There you'll find more elaboration of my few ideas on inquiry-based science learning.

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The Five Fundamental Lessons of Astronomy

These 'lessons' are really topics for learning, or if you like gifts that Astronomy has made to our growing picture of the world. I've written them from the perspective of fascination with the *what* and the *how*. I can't really do them justice of course; rather I've tried to sketch the basic ideas in an open-ended way.

Lesson 1. The Stardust Hypothesis

This universe had a 200 second window to build heavy elements out of protons and neutrons. (Unfortunately I have to cite these facts *ex officio*.) Helium-4 proves to be so stable that it crashed out about ¼ of the heavy matter and held onto it—there were no stable 8-nucleon configurations which made a bottleneck—so that nothing heavier than Helium was manufactured in any quantity in the early universe beyond a few handfuls of Lithium and Beryllium. And yet today here we are, all carbon and oxygen and nitrogen and silicon and calcium and these other heavy elements. In the mid-20th century observational astronomy and nuclear physics came together to account for the existence of all these heavy elements: They are built inside stars as byproducts of nuclear fusion burning. These stars—in some cases—subsequently spew out their guts into the cosmos if they are sufficiently large, and this happens at the end of their life cycle. Hence the rather poetic notion that our existence is only possible because we are built from the ashes of ancient, dead stars.

Lesson 2. Our Island Universe.

An Amusing Activity: Go to the Hubble Space Telescope photo archive and search on "Galaxy". You'll get a lot of hits that lead to good-quality photographs and explanatory text for a number of galaxies. Print out 15 or 20 galaxy pictures on a decent printer and attach to their backs some of the given explanatory text. Put each galaxy in its own manilla envelope and write two numbers on the outside: A number from 1 to 24 and a number from 3 to 20, both chosen at random.

Place a 24-hour clock in the center of a room and have students place each envelope according to its clock angle and distance from 3 to 20, which are to be measured in some standard way such as shoe-lengths. Once the envelopes are placed, the students go around pulling out the galaxies and placing them visibly on top. The floor now resembles an Archipelago of galaxies.

"…ok, you've got this bathtub, and it's made of ebony…" –Ford Prefect

Lesson 3. The story of the Incompetent Projectionist.

If distant galaxies are all receding from us, the further ones faster, then either they've all been hit like baseballs or—more difficult to comprehend—the space in which they are all embedded is itself expanding in all directions like a very large three-dimensional taffy. What's more this rate of expansion appears to be accelerating. I can't even begin to tell you what cosmologists have made up to explain all of this, except that it sounds suspiciously like the basis for a religion for people who carry light sabers. Suppose you made a movie of all this but your projectionist threads it in backwards. Now everything is

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moving towards everything else, a process that looks like it will continue for negative 13.7 billions years, until everything reaches the same place. A universe that originated from a single point is simultaneously marvelous and disturbing, at least to my mind. What came before?

Lesson 4. Michael Crichton's Misunderstanding.

Here is a little essay on the nature of science and how it is not so carefully constrained and well-defined as some people seem to think.

Michael Crichton, the author of Jurassic Park and other works of fiction, famously gave a speech some years back deriding the Drake equation as non-science. The Drake equation is a speculative means of estimating how many intelligent civilizations there are in the galaxy. It is an interesting way of thinking about life beyond earth, a possibility that Astronomy shows us is entirely reasonable to begin with because we now know that all those stars in the night sky are suns much like our own.

The Drake equation makes no assertions about the existence of life elsewhere; it merely posits a series of constants that are multiplied together to arrive at a speculative estimate of how many stars in a galaxy might support creatures who operate radios. The underlying facility in working with the Drake equation is imagination, a crucial part of being a scientist. This is the boat I suggest Mr. Crichton missed in his speech: Scientists don't know the answers to their questions in advance; rather they make progress by means of guesswork, trial and error, intentionally making mistakes, fumbling around in the dark, making wild speculations and just generally letting their imaginations roam unhindered by preconception. They are also unhindered by ideas of what they may or may not think about. It's often not the prettiest process, but it has a wonderful mechanism in place that acts as a safety net at the end of the day: Verifiability.

When a scientist reaches (or jumps to) a conclusion, it is only the beginning of that conclusion's existence. No matter how crazy it is, it has the right to exist as such subject to subsequent verification or disproval. So if 100 years ago you were to walk up to me on the street and say "I have this idea that the continents look like interlocking puzzle pieces because they were once connected, and furthermore these puzzle pieces slide around on the earth across some hot plastic glorp 150 kilometers below the surface" then I would be obliged to nod politely and inquire how you intended to verify the notion. If I were to laugh and walk away then I would be a fool, because of course you were absolutely right. (Most scientists at the time laughed and walked away.)

Exobiology or Astrobiology is now a serious discipline complete with departments at universities and a growing catalog of books. It is intimately connected with the search for extra-solar planets, many of which we have located by their wobble-inducing influence on their host stars. Then there is this pretty idea as well: If we happened to build two very nice telescopes in space (like the Hubble but bigger), and if we pointed them at the same star, and if we then combined their received light in such a way as to cancel out the center of their respective fields of view we could detect any orbiting exo-planets directly (since the starshine in the center would be cancelled out). We could even direct the light from

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those planets into a prism and analyze the resulting spectrum. If one were to analyze the spectrum of earth in this way it would appear to have the potential to support life as we know it. Of course looking at the earth to see if it could sustain life is a rather circular thing to do; the point is that we might directly see other possible earths orbiting other stars some day.

"Oh Tiger Lily, I do wish you could speak!" –Alice

Lesson 5. The Garden of Live Flowers

When Alice walked out of the Looking Glass House she found (as she had rather hoped) that it was surrounded by an immense garden. On the far side of the garden was a hill she decided to visit in order to have a better view of the surrounding countryside. In the course of reaching it, two things happened. First she learned that Looking Glass flowers *could* speak (because their beds were not so soft) and second if she wished to get to the hilltop she could only make progress by choosing a path that headed in precisely the wrong direction. I belabor this part of Lewis Carroll's narrative because Alice's expectations were built on her life experience in our 'normal' world, but these were often confounded in the Looking Glass world. By analogy the Universe out there continues to throw wrenches into our picture of physical reality. We are I think justifiably proud of this picture—it accounts for an awfully large number of observable phenomena—but Astronomy is definitely the wrench in the machinery, the fly in the ointment, the flower in the garden who can talk.

In brief detail: When we found in the 1970s that the arms of our galaxy were spinning in their extremities much faster than we could account for, we had discovered incontrovertible evidence that we were Missing Something Really Big. In fact we were missing mass, about five times more mass than could be accounted for by observation (stars, gas, the usual constituents of our galaxy). The terrifying or if you like wonderful upshot is that while we used to think we understood what was going on, now we're sure we don't. The current best idea for the missing mass is that it is some kind of matter that can't be seen by normal means. Hence 'dark matter'. What is dark matter? And why does it operate on a scale of the galaxy to such effect but does not appear to affect the orbit of our moon?

Voila, an arbitrary collection of five sets of ideas given us by astronomy. And this leaves out much more than it includes. It leaves out the many fascinating and exotic things we believe are out there. It leaves out the connection between the earth and the moon. It leaves out the way that Europa disrupts Jupiter's magnetic field. And so on.

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Appendix A: Teaching Notes on Rainy Night Astronomy

Contents

Part 1. Six Steps to the sky

The purpose of this section is to provide some starting resources for the person interested in getting to know the night sky better. It is written for early April… I hope to update it for other times of the year as well, but even if it is October this should convey the general idea I'm going for: I'm no expert but I've made a little progress and since astronomy is enormously fun I want to share that. I've broken the astronomy learning process into six steps and so without further ado here they are…

Step 1. Learn your way around the night sky by eye.

a. Acquire a planisphere or star chart.
b. Tape or rubber-band several layers of red cellophane over a small flashlight.
c. Wait until a dark clear night, bundle up, go outside, preferably to a place away from artificial lights.
d. Look up!

On a dark night your eyes will become adapted to the darkness in about thirty minutes. The red cellophane covering the flashlight allows you to refer to your star chart in the dark without disrupting your dark-adapted eyes too much.

Knowing your way around the sky means learning constellations and recognizing patterns of stars (called *asterisms*). You probably know one or more already; if so, start from there. Orion and the Big Dipper (part of Ursa Major) are two easy constellations to identify; they make a good starting point so one plan is to try and bridge them by learning the constellations in between. The Big Dipper is very visible at this time of year, high in the sky and rotating counterclockwise as the night wears on. Orion is a little harder as he is setting on the west-southwest horizon as the sun goes down.

Some Encouragement

Before going on with procedure, I want to briefly mention that stargazing is not "easy" but in my opinion it rewards the effort we invest. So let's take a moment to imagine the process and what is going to be difficult about it and what the rewards are.

Suppose you've decided to give it a try, and you have a dark night and no moon, and you've picked a good dark spot. You drive or walk there with your star chart and maybe these notes in your hand and you have your red flashlight and hopefully a pair of binoculars and some warm clothing and if possible a folding camp chair and maybe a thermos full of hot tea. So here's the first hurdle: You had to give up maybe playing

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video games or watching a movie or a TV program in order to get out here… and it's a bit chilly out.

Take heart! All over the dark side of the world at this same moment there is a small group—maybe a few thousands—of people doing exactly what you're doing!

Now you set down your chair and your stuff, you have a seat, and you look up into the night sky. It is an unfamiliar sea of pinpoint lights and you think "oh no! this is harder than I thought!" At this point you reach for your star chart and your flashlight and are about to turn the flashlight on to look for constellations. Wait! Don't do it! Just plan to sit there for ten minutes looking at the sky. Let your eyes adjust; they will become more sensitive and you will see more. Pick a set of three or four bright stars close together and connect them in your mind with lines. It doesn't matter whether they are all in the same "official constellation". You are making up a constellation of your own. Let's suppose you decide to call it The Duck. Look away to somewhere else, then come back and find the Duck again. Do this in a couple places until you can go back and forth and spot your constellations easily again. It takes a little patience. If you're cold have some tea… or hop in the car to warm up (but don't turn on the headlights)… or if you're just cold and miserable go home and wait for warmer weather. Don't not-have-fun!

Once you have The Duck memorized you can realize this: A little corner of the sky, *your* corner of the sky, is now familiar to you. That can be your starting point. You can look at the pattern of stars that make up The Duck and say "this is familiar, even if the rest of it still looks like a bunch of random dots." And that's how you get on your way to knowing your way around the sky.

Right now in early April for me this starting point is an equilateral triangle of three bright stars in the southwest. One is red-orange, one is blue, and one is white. The orange one is furthest west, the blue one is furthest south, and the white one is the highest in the southwest sky. I have since found that these stars (like all bright stars) have proper names. They are respectively: Betelgeuse, Sirius, and Procyon. Once I have their names I can look them up and I find:

Betelgeuse is a red supergiant; if we were to swap it with the sun the entire orbit of planet earth would be inside this star. It is quite possible that Betelgeuse will one day implode in a type-II supernova. The light we see from Betelgeuse left the surface of the star 427 years ago.

Sirius—often called the Dog Star—is the brightest star visible from earth (next to our sun). Sirius is actually a binary star system where the two component stars are called Sirius A (the bright one) and Sirius B (much fainter). Sirius B is a type of star called a white dwarf; it is very old and dense being the size of the earth and having the same mass as our sun. The light we see from Sirius left the surface of the star 9 years ago.

Procyon rises just before Sirius (the dog star) in the northern hemisphere and in fact the name Procyon means "before the dog". Procyon is a binary star system, a white dwarf

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and a bright F-class star which has just finished burning the last of its hydrogen fuel. Hence Procyon is about to expand into a red giant (like Betelgeuse), a fate also awaiting our sun in another five billion years. The light we see from Procyon left the surface of the star 11 years ago.

Now with only these three bright stars to begin with I have unique stories for each and a corner of the sky that looks familiar to me. I also see the three dimensional nature of the universe, since two of these stars are about 10 light-years distant while Betelgeuse is 43 times further away.

I have attempted to sketch out what makes beginning amateur astronomy difficult (inconvenient and intimidating) and what make it worth the effort. In the last century we have learned so much about what is going on up there; all this knowledge is readily available in books and on web pages, and the ultimate reference, the book-of-books, is right outside the back porch on a clear dark night. For most of my life the night sky was just a shell of dots that I would glimpse every so often on my way from the front door to the car. Taking the time to learn the sky transforms that meaningless shell of random dots into a deep ocean of familiar, even friendly worlds.

Procedure for Learning the Sky

A general procedure for learning the sky is to refer to your reference chart and then to the sky and then back to the chart and back to the sky and back and forth in this way many times as you identify new constellations. There are details to this process—like which way to hold the sky chart and how to cope with a bright moon—so I've given some elaborations below. The other thing to keep in mind is that studying star charts at the kitchen table is a very useful way to prepare for observing. It will print the patterns in your mind's eye; once you are out under the stars you will have less work to do in referring to the star chart.

Planisphere

A planisphere is a sky chart consisting of two discs of paper or plastic. The smaller one turns against the background of the larger one; it has a window or hole cut in it to show the "local" view of the sky, that is, how the sky will look at a given time of night on a given day of the year at a given latitude. Here in Colorado we are at about 40^{o} N latitude so a typical planisphere will work great.

It is also possible to get a simpler sky chart by visiting www.skymaps.com and printing out the sky chart for the current month. This has the advantage of telling you where the planets are as well.

The *main thing* is to get your star chart set to the appropriate view and hold it in such a way that it "matches" the sky. For example with a planisphere:

1. Rotate the inner disc until the **time of day** matches the **day of year**. The window now shows what the sky looks like (in miniature).
2. Facing south hold the chart at waist level so that "north" on the chart is pointed south.

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3. Now lift up the sky chart over your head so that you can still read it and so that North points north. Your chart is now a properly oriented map of the sky above you.

Of course your sky chart is a tiny representation of the sky above you. The main challenge is therefore to learn how to refer back and forth between the chart and the real thing. It takes some patience and is definitely more fun if done with a friend.

More tips on identifying constellations and star-hopping
Choose a bright star you do not know and notice its relationship to stars in a constellation you do know. That is, notice the geometric direction and distance relative to the familiar constellation. An example is to notice that the bright star Arcturus is "pointed at" by the arc of the handle of the big dipper. Once you notice this on your chart you can look at the big dipper in the sky and make the same geometric connection. Sure enough, extend out past the handle of the big dipper on a big arc and there will be a bright star, and that's Arcturus, and you're off!.

The danger in this method is sometimes having planets sneak into the picture. They are probably not going to show up on your star chart in their proper position (unless you printed it from skymaps.com this morning) so the wandering planets might confuse matters. Right now for example Saturn is near Gemini.

You can use the same idea for groups of stars as well. Since we are quite good at seeing patterns, it often works to look for the pattern in the star chart and then look up into the sky for the corresponding pattern. Or you can start with the pattern in the sky and look for it on the star chart. Once you make a recognition and practice it a few times you will find you have expanded your mental map… and then you can go to the edge of your map and continue the process until everything is filled in. This takes a bit of practice and you can think of it as building a jigsaw puzzle that will eventually cover the sky. Just like a jigsaw it can take awhile and you'll periodically need to refresh your memory.

A note on light pollution: City lights or the moon can drown out fainter stars but this can work to your advantage in making your map. Brighter stars will still be visible, simplifying the sky. You don't need to drive 30 miles out on country roads to practice learning the sky.

Some stars and constellations that are easy to locate include (in April):

- Orion sits low on the western horizon at sundown in April.
- Sirius, the brightest star in the sky, is near Orion and low on the Southwest horizon. It is the bright star in the constellation Canis Major (the greater dog).
- Orion's upper right shoulder is a bright orange star called Betelgeuse. Notice on a star chart that Betelgeuse, Sirius and another bright star to the east (Procyon) make a large equilateral triangle. This triangle is easy to see and makes a great geometric basis for finding other stars and constellations. Procyon is the brightest star in the small constellation Canis Minor (the lesser dog).
- Above the line connecting Procyon and Betelgeuse is Gemini. It looks like a connect-the-dots for two stick figure twins standing next to one another.

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- Nearby just to the east of Gemini is the planet Saturn, actually in the constellation of Cancer (which contains only fainter stars).
- Leo is high in the sky continuing east from Gemini. Leo looks to me more like a stick figure horse than a lion.
- The big dipper is to the north of Leo, part of the constellation Ursa Major. If you know Orion and the Big Dipper now you can connect them via the constellations visited so far: Canis Major, Canis Minor, Gemini, Cancer, and Leo.
- The North Star: Locate the outer two stars of the big dipper and extrapolate their line to the north to the bright star. It is sometimes called Polaris or even Cynosure. While the other stars will wheel around the sky in the course of the night, the North Star stays fixed in place.
- The constellation of Cassiopeia is shaped like a W and roughly opposite Ursa Major around the North Star. It too will be low on the horizon in April, to the north.
- Bootes is a constellation that looks like a lopsided ice cream cone, with Arcturus the bright star at the bottom of the cone. Find the big dipper in Ursa Major and follow the arc of the handle out away to arrive at Arcturus.
- In between Bootes and Leo is a fainter but pretty constellation called Coma Berenices.
- Finally suppose you see the last star in the handle of the big dipper and have followed the arc of the dipper handle out to Arcturus. Go the same distance again in that direction and you should find a bright star on the southeast horizon. This is in fact not a star at all but the planet Jupiter.

Stay awake later (or wait until later in spring and summer) to see more constellations rise in the east to spin westward. Stars near the North Star never set below the horizon from our perspective.

Step 2. Learn the Whos/Whats/Whens/Wheres/Whys/Hows of Astronomy
It’s fun to see the galaxy in Andromeda with just your eyes. It’s even more fun to look at it through binoculars. Through a telescope it’s better still. But when you realize the light from it has traveled for the past two million years just to fall into your eye it becomes cool on a whole new level. Knowing what’s going on up there is a great complement to observing stars and planets.

Here are a couple of ways of learning about the what’s up in the sky. See also Part 2 of this pamphlet, a **Bibliography**.

First, I suggest hitting the library! Grab a smattering of books that look interesting. I highly recommend Timothy Ferris’ books including Seeing in the Dark and Coming of Age in the Milky Way. Practical methods for learning your way around the sky can be found in The Backyard Astronomer’s Guide. Purchase or otherwise obtain a copy of the Audobon Society Field Guide To The Night Sky for a more detailed general reference that includes a whole lot of constellation mythology.

Next, seek out the local astronomy club. You can Google search the name of your town or state plus “Astronomy Club” to locate the local enthusiasts. In Boulder that will be

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www.boulderastro.org. Visit a planetarium (in Boulder, Fiske Planetarium on the CU campus, in Denver, Gates Planetarium at the Museum of Nature and Science). Stop by the magazine rack at your local bookstore and pick up a copy of *Sky and Telescope* or *Astronomy* magazine. (Just don't stare too long at the telescope ads.)

Step 3. Before you start thinking about telescopes: Grab a pair of binoculars!

- Binocular astronomy is a far superior path of approach for most beginning observers. Binoculars are lightweight and easy to transport. They allow you to grow your understanding of the sky without having to fuss with knobs and tripods and lenses and eyepieces and so on. Binoculars permit you to see lots and lots of cool things you can't see with the naked eye; they are the logical next step in observing. If you get to the stage where you want a more stable field of view, binoculars can be attached to a simple cheap tripod.
- Don't miss the opportunity to watch the moon's phases as it travels around the earth, and also make sure to pick out any planets visible. See how much detail you can pick out; as with your other observing targets you will be amazed at how much you can see with binoculars, and this will in turn prepare you to decide if and when to make the jump to a telescope.
- After this introduction I have included a list of objects in the sky to look for using binoculars. This is followed by some book and web-page references which will also be quite helpful.

Step 4. Teach Astronomy To Other People!

Whether you talk about it informally over lunch or get your friends together to discover the sky, there is no better way to motivate yourself to discover more than to share your understanding with other people. Little brothers and sisters might make good subjects as well, or older brothers and sisters if that's what you have.

Step 5. Okay, so you're ready for a Telescope

Ok, I admit it: Telescopes are synonymous with astronomy. Even though I have tried to make the case above that a telescope isn't necessary to be an amateur astronomer, for the sake of completeness I should describe the advantages of the telescope. I mentioned above that fiddling around with scopes is harder work, so the main point is that getting a telescope is something you do when you know you're ready for it. Using a telescope is challenging precisely because telescopes are so powerful; they require more care and practice to set up and operate.

Also to be fair some telescopes are designed to be fast to set up, even very powerful ones. In any event by the time you are ready for a telescope you will have long since thrown away this little pamphlet! Nevertheless looking ahead I can give you an idea of what you'd be thinking about if you get to the that stage.

Design (basic telescope architecture)

Your pupil is at most about 7mm across, a pretty tiny window for light to enter your eye. Imagine if it was instead 10 inches across; you would collect more light and be able to

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see fainter things. Combine this with the ability to magnify those faint things and you get the point of a telescope: A large light-gathering opening that magnifies a field of view.

There are two general categories of telescope: Refractors and reflectors. Refractors employ the traditional lenses-and-tapering-tube-to-eyepiece. Reflector telescopes direct the incoming light by means of mirrors rather than lenses. They tend to be bulkier than refractors and have commensurately better light-gathering capability. They also tend to cost more.

The third important factor in imaging faint small objects (beyond light-collecting area and magnification) is the shutter speed of the recording device. Humans have a shutter speed of somewhere around 1/6--1/10 of a second; that is how often our eyes "take pictures". A camera on the other hand can be left "on" for much longer periods of time. Hence one factor in one's choice of telescope is whether or not photography is part of the plan. If photography is *not* part of your immediate plan and you just want to look at the sky with your eyes then the best telescope for your buck will likely be a Newtonian reflector in a Dobsonian or alt-azimuth mount. These are fast to set up, easy to use, and have lots of light-gathering power which will permit you to see faint objects like distant galaxies. (These scopes were originally designed by Isaac Newton and John Dobson is a modern chap who figured out a simple and rugged way of making them easy to point.)

Cost and what features you want to pay for
In 2006 an inexpensive telescope with capabilities far beyond Galileo's wildest dreams is going to run about $200. A really really powerful Dobsonian with 10" aperture can be had for $650, probably the most a new amateur astronomer would need to spend to have more telescope than they'd know what to do with.

Suppose you suspect a telescope is in your future; here is another approach to choosing a scope. Simply hang out with some astronomy club people on observing nights (star parties) until you are ready to steal one of their telescopes for your own personal use. When you reach this point, instead of stealing the telescope simply write down the type and brand and go get one of your own.

By the way, if you learn to navigate the sky you can skip buying automated starfinder hardware/software. This kind of gadgetry has become popular in recent years because it lets a person find objects with no effort… but I have to say I'm not a fan of the idea. I love astronomy because it engages my mind so I'm suspicious of advertising that describes observing with the term "no-brainer". By skipping the starfinder feature you can buy more telescope on a given budget.

The main point I make about telescopes is to let one's passion for observing drive the pathway to equipment. Often people who become entranced with the equipment buy it but don't wind up using it, and again this is because getting out and observing is challenging. So now we return to the dark secret of observational amateur astronomy, so important that I'm giving it a separate last section of its own: One more time, it's important to keep things fun in the face of the inconveniences of amateur astronomy.

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Step 6. Stay Warm
It is impossible to over-emphasize that finding the time and the place to observe the sky is not a simple matter for most of us. In the first place it happens at the end of the day, so we are tired to begin with. This is why I advocate investigating amateur astronomy at a gradual easy pace that keeps things fun. Just knowing a few constellations can be immensely rewarding; membership in the club is free and you can pause in your pursuits any time you like!

There are many tricks to keeping astronomy fun, incidentally, not least of which is to go to bed at 8 pm and get up at 4. This solves the end-of-day fatigue obstacle and gives you a few hours to observe before the day starts for most everyone else. Also: Have a thermos of tea or cocoa or coffee ready. Also: Bundle up in clothes that will keep you warm and still permit you to move around comfortably. Be prepared to take breaks involving some fast walking to warm up. If you are crazy or wealthy enough, contact Gerbing Heated Clothing and order an electric vest that connects to a car battery. (You will need to either keep your car running or bring along a spare battery to avoid running your car battery down with your vest!)

In summary you want to be comfortable while you are observing because your enthusiasm and love for the night sky will only take you so far. My first session with a nice telescope was in Fairbanks Alaska and I was excited enough that I spent forty five minutes literally crouched in a field of snow looking through the eyepiece before I got too cold to continue. But it's hard to maintain that type of enthusiasm… so now I dress warm and try to remember to bring along a little chair.

Part 2. Bibliography
Here are some resources to get started with. The best way I know to browse online is to simply find the titles at Amazon.com and read customer reviews. However if you suspect you might be a future amateur astronomer and you could only get one of these books I'd recommend Nightwatch by Terence Dickinson.

Books
How To Get Started Observing, Star Charts etcetera
Nightwatch by Dickinson
Exploring the Night Sky with Binoculars by Chandler and Davis
Binocular Astronomy by Crossen and Tirion
Star Watch by Harrington
Turn Left At Orion by Consolmagno and others.
The Backyard Astronomer's Guide by Dickinson and Dyer
The Audobon Society Field Guide To The Night Sky

Learning about astronomy
Full Moon by Michael Light (Apollo mission photography)
A Man On The Moon Andrew Chaikin
Coming of Age in the Milky Way by Timothy Ferris

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Seeing in the Dark by Timothy Ferris

Film
For All Mankind (documentary on the Apollo missions)

Web Resources
http://www.boulderastro.org
http://www.badastronomy.com
http://www.nasa.gov
http://hubblesite.org
http://www.uvaa.org/BinocularResources.htm
http://www.skymaps.com
http://www.scitoys.com

The Author's Personal Website
http://www.robfatland.net

Part 3. Modifying Your Spectroscope

The spectroscopes we handed out at the Astronomy party are very simple to build. We simply cut out a rectangular hole in the bottom of a coffee cup, glued a piece of clear plastic in place over it, and put the lid on. The only tricky part is rotating the lid so that the drink hole "lines up" with the color-ghosts of a fluorescent bulb. (If this doesn't make sense then you may not have been at the Astro party; in any case you are welcome to email me if you have questions.)

The clever bit of the spectroscope is the little clear-plastic window. What is that thing? What makes it work? First it is technically called a "transmission diffraction grating" but what it *really* is is a bunch of nearly-invisible lines, very thin, drawn on the plastic that cause it to behave like a prism, splitting up white light into colors. When we look into the spectroscope at an *incandescent* light bulb we see a rainbow or ***spectrum***. When we look at a *fluorescent* bulb we see several individual colors separated, as if someone has cut out bits of the complete spectrum. (This is how we "fingerprint" stars and determine what is in their outer atmosphere.)

The spectroscope will work fine if you look at bright stars (other than the sun!) but you can modify it if you like to make it more effective for seeing details of a spectrum. There are two steps involved: Cover it over to keep out excess light, and narrow the drink hole to be a thin slit.

Covering a spectroscope is easy to do with some aluminum foil and scotch tape. You wrap the foil around the spectroscope everywhere except at the window and the drink-hole in the lid.

Making the drink-hole (which is a little oval) into a slit will require some more careful work. The easiest approach would be to take two small bits of aluminum foil from the edge of the foil roll so they have very straight sides. Tape these in place over the drink

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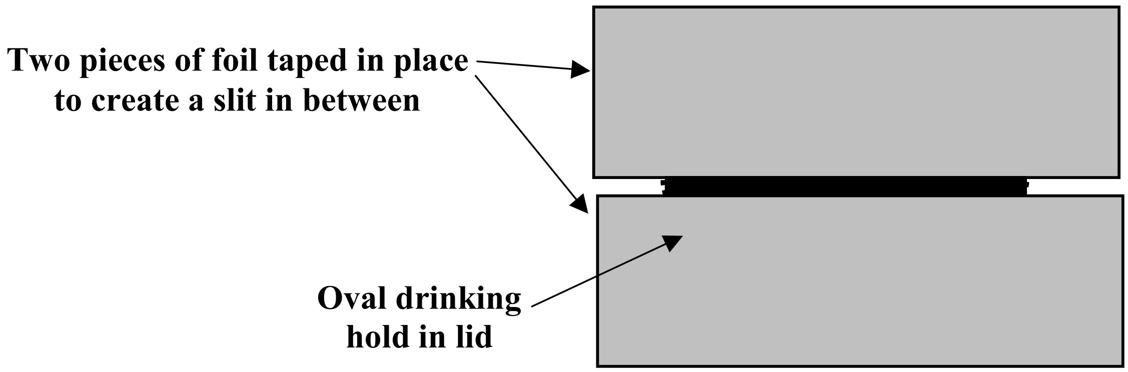
hole in the lid leaving just a tiny gap in between them. This will be your spectroscope slit. Since it allows in a much thinner beam of light, the resulting spectrum will be sharper.



If you are interested in spectroscopes you can find more construction ideas and more things to look at described online here:

http://www.cs.cmu.edu/~zhuxj/astro/html/spectrometer.html
http://www.scitoys.com and click on Light and Optics and then click Building a Simple Spectroscope

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Part 4. Binocular Objects of Interest

Let's suppose you've started to learn the constellations and have a star chart for reference (and remember you can get good star charts for free on the web, starting with www.skymaps.com). You've got a pair of binoculars in your hands and are ready to push beyond what you can see with just your eyes. But where to look?!

Karen Pierce compiled this list of "things to look for with binoculars" and she placed it on the internet for public use. It assumes some familiarity with terminology and star charts. Finding these objects will therefore take a little experience and/or preparation, for example using the Audobon field guide. They are listed here by constellations alphabetically and I have highlighted some of particular relevance for evenings in April.

BINOCULAR OBJECTS

Compiled by Karen W. Pierce

Andromeda

M31 – The Great Galaxy in Andromeda

The most distant object that can be seen with the naked eye, it is superb in binoculars. This galaxy is our closest neighbor, 2.2 million light years away.

R Andromedae

This variable star has a range of 9 magnitudes.

NGC 752 and The Golf Club

Open cluster about 5 degrees from Gamma Andromedae. Because it is such a large object it is easier to see through binoculars than a telescope. There are about 75 stars in this cluster. Look 1 degree west of NGC 752 for a small pattern of 7 sixth and seventh magnitude stars in the shape of a golf club. NCC 752 reminds some as a golf ball next to the head of the club.

Aquarius

M2

A globular cluster that is 6.5 magnitude is easily found with binoculars. It is 37,000 light years away and approximately 150 light years in diameter. Although detail is not seen it is well worth finding. This cluster contains more than 100,000 ancient stars that may predate the Milky Way.

Aquila

R Aquilae

This variable star varies in magnitude from 6 to 11.5 of a period of 284 days.

NGC 6709

A pretty open cluster consists of about 40 closely knit stars against an already rich hackground of stars. This is approximately 3,100 light years from earth.

NGC 6738

This open cluster is very similar to NGC 6709. Once located, small binoculars may reveal a few of its brighter stars.

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Auriga

M 36
Bright open cluster contains about 60 stars of 8th magnitude or fainter. Collectively they shine at 5th magnitude and lie 4,100 light years distant.

M37
An open star cluster about the size of the moon, it is one of the finest in the northern sky. It has at least one red giant near the center, giving the appearance of a "ruby in a field of diamonds." M37 lies about 4,600 light-years away. Binoculars will show this cluster as a misty spot. In a 6-inch telescope more than 100 stars can be seen.

M38
This small, open cluster of stars resembles an "X" when seen in wide field eyepieces. It contains about 100 stars and is about 4,200 light years away.

The Minnow
Another binocular highlight is an asterism sometimes called the Leaping minnow; a little group of 5th and 6th magnitude stars. Have you seen this cluster?

Cancer

Saturn!!

M44 - Praesepe or The Beehive Cluster
One of the sky's finest open clusters is easily seen from the city with binoculars. This cluster was named in 1996 as Utah's astronomical object. There are over 200 stars in Praesepe, spread over 1 ½ degrees, and are best seen in binoculars. Galileo was the first person to see the Beehive through a telescope. He saw more than 30 individual stars. It is about *525* light years away.

M 67
This 6th magnitude open cluster has 500 faint stars spread over ½ degree. Can be found with binoculars but easier with a small telescope. It is about 2,500 light years away.

R Cancri
A bright long-period variable; At its maximum it is magnitude 6.2. It varies down to 11.2 and back in a year.

Canes Venatici

M3
A rare gem in the northern sky, this globular cluster is some 35,000 light years away and 200 light years across. It contains perhaps 500,000 stars.

M 51 - The Whirlpool Galaxy
This famous galaxy appears as a round 8th magnitude glow with a bright nucleus. The distance to this galaxy is approximately 35,000,000 light years.

Canis Major

M41
A beautiful open cluster of about 80 stars surrounded by a rich field of background stars. This is perhaps the dimmest object visible without optical aid. Aristotle noted this object in 325 B.C. as one of the mysterious "cloudy spots" in the sky. This cluster is about 2,200 light years away.

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NGC 2362
This open cluster is often overlooked but is a beautiful sight. At magnitude 4.1 it is easy to find, and is 4,600 light years away from earth.

The Boomerang
Look about 1 degree from Delta Canis Majoris for a half circle of 7 stars of 4^{th} to 6^{th} magnitude. It resembles a boomerang. The brightest star near the bend is Omega Canis Majoris.

Collinder 140
This bright, large open cluster is near the tip of the dog's tail. Some 30 stars of magnitude 5 to 9 are gathered here. The main ones form a narrow pattern reminiscent of the famous "Coat Hanger" asterism found in Vulpecula.

Capricorn

Alpha Capricorni
This wide double star has a separation of 6 arc minutes -- a naked eye test for a night's clarity and steadiness. The star is a double by coincidence, but each star is itself a true binary.

M30
This 7.5 magnitude globular cluster is 40,000 light years away and is bright, large and a little extended.

Cassiopeia

Owl Cluster - NGC 457
This is a very interesting object to see. In a small telescope some people see an Owl perched on a limb while others see E.T. This cluster is believed to be about 9,300 light years away and contains several thousands of stars.

M52
This open star cluster is large and rich, containing about 200 stars. It is magnitude 6.9 and lies 7,000 light years away.

M103 and NGC 663
A faint, 7.6 magnitude open cluster near Delta Cassiopeiae appears to look like a tiny puff of cotton. Continuing on find NGC 663, which is a larger and fuzzier open cluster. Other clusters are also binocular-visible in this constellation. Try finding NGC 129, NGC 7789, NGC 225, and NGC 547. How did you do in finding these?

Centaurus

Alpha Centauri
This star is only 4.3 light years away and is the Sun's nearest neighbor. One of the prettiest binary stars, its two components revolve around each other once every 80 years.

Omega Centauri - NGC 5139
Southern skies are needed, but it has been seen from the Rush Valley Site in Utah. This globular cluster is one of the finest examples in the entire sky with perhaps 1 million members. Only 17,000 light years away, it is one of the closest to us. It is oval in shape and with magnitude 3.7 is very easy to find.

Cepheus

Delta Cephei
One of the most famous of the variable stars, it is the prototype for the Cepheid variable. Its highest magnitude is 3.5 and it fades to 4.4. It completes a cycle every 5.4 days.

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Mu Cephei

This star is so red that it is often called the Garnet Star. It varies in brightness between 3.6 and 5.1 irregularly over hundreds of days. This star is approximately 1,550 light years away.

Coma Berenices

Mel 111 ("Melotte 111") The Coma Berenices star cluster. The constellation of Coma Berenices itself has no bright stars and is hard to distinguish, but it is a remarkable area of sky and is beautiful in binoculars. One of the finest open star clusters for binoculars.

M53

This fine globular cluster is about 3 arc minutes in diameter and is located close *to A!pha Comae Berenices*. Similar to M13, this cluster is about 60,000 light years away and is about 8th magnitude.

Corona Borealis

Another fine binocular constellation comprised of a small semi-circle of faint stars, very distinct. It is interesting to see how rnany stars can be seen within the "Crown". 7 x 50 binoculars reveal at least 15 stars.

Cygnus

North American Nebula - NGC 7000

One of the sky's best examples of a bright nebula, this giant cloud is illuminated by brilliant Deneb, which is only 3 degrees to the west. Because of its size, the nebulae is difficult to see in a telescope: it is best seen with the naked eye at a dark site. This nebula is about 1,600 light years away.

M29

This 7th magnitude open cluster lies in an area of high dust absorption so it is sometimes overlooked. It is 7,200 light years away and contains a dozen 9th magnitude stars.

M39

This loosely bound open cluster of about 25 stars is seen at its best through binoculars, and loses its pizzazz in larger apertures. On a clear night at a dark site it may be seen with the naked eye, as Aristotle apparently did around 325 BC. This 4.6 magnitude cluster is only about 900 light years away.

Delphinus

A small constellation (only about 6 degree long) with a distinctive shape, easily seen through binoculars. It looks like a kite with a tail. Can you make out the different colors of the stars that make up this constellation?

Gemini

M35

This bright 5th magnitude open cluster is visible with the naked eye, is beautiful through binoculars and spectacular in a small telescope. It contains about 300 stars and is about 2,800 light years away.

Hercules

Hercules Cluster - M 13

The most dramatic globular cluster in the northern sky, it is faintly visible to the naked eye as a fuzzy spot. Easily seen

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through binoculars with a magnitude of 5.9, it lies 23,000 light years away. Its diameter is 160 light years and has more than a million stars.

M92
Another excellent globular cluster in Hercules, it is often mistaken for M 13 because they are so near to one another. This cluster is of 6.5 magnitude and is about 35,000 light years away.

Hydra

M48
A large open cluster best seen through binoculars or a wide-field telescope. It is moderately bright at 5.5 magnitude but is spread out. M48 can be seen with the naked eye at a dark site. This cluster contains about 80 stars and is 1,700 light years away.

M83
At 8^{th} magnitude, it is one of the brighter galaxies visible in binoculars. There have been four supernovae here in the past 60 years. This galaxy is very close to us at 10 million light years.

Leo

M65 and M66
These two spiral galaxies near *Theta Leonis are* visible in binoculars but give a better view in a telescope. They are about 25,000,000 light years distant and are separated from one another by 180,000 light years.

M95 and M96
These spiral galaxies are said to be visible with binoculars, although they are both 9' magnitude. Maybe you will have success in finding these two galaxies that lie 29,000,000 light years away.

NGC 2903
If the sky is dark, a challenge is to find the galaxy NGC 2903. It should not be hard to find in 10 x 50 binoculars.

Lepus

M79
This 8^{th} magnitude globular cluster can be difficult to find because it is large, rich and compressed, but with dark sky conditions it should not be hard to find. This is south of Orion in the sky. It is about 54,000 light years away.

Libra

Jupiter!!

Lyra

Epsilon Lyrae
This is a superb example of a "double-double" star. Slight optical aid will show two 5^{th} magnitude stars. Both are themselves doubles, with separation under 3 arc seconds. A small telescope will split both of them. This whole system lies 180 light years from earth.

M56
This fine globular cluster is often overlooked because it is so close to M13. The magnitude of this cluster is 8.2, and is 46,000 light years from us.

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Monoceros

M50
This beautiful open cluster is easy to find being 6th magnitude but is not as spectacular as others. Some of the 80 stars in this cluster are arranged in pretty arcs. This may be seen naked eye on the best of nights.

NGC 2244 and NGC 2237
Ten degrees east-southeast from Orion's giant Betelgeuse, a narrow rectangle formed by three nearly parallel pairs of stars should be visible. These stars belong to NCC 2244, a bright but sparse open cluster that stands out nicely in any binocular. The faint haze encircling NGC 2244 is the famous Rosette Nebula, NGC 2237. Binoculars are ideal for glimpsing the low-surface-brightness of the Rosette.

Ophiuchus

M9, M10, M12, M14, M19, and M62
These globular clusters provide a range of examples of different concentrations of stars. All are visible in binoculars but require a 6 or 8-inch telescope to really do them justice.

IC 4665
This is a big but often overlooked open cluster located near Beta Ophiuchi. On a dark night it is visible to the naked eye as a hazy splotch nearly I degree across.

Orion

The Great Nebula - M42
Plainly visible to the naked eye it can clearly be seen in binoculars in the city. M42 lies about 1,600 light years away and is over 30 light years in diameter.

M43
This is a small patch of nebulosity just north of the Orion Nebula. In fact, the M42 complex is the brightest part of a gas cloud covering the constellation of Orion at a distance of some 1,500 light years.

Pegasus

M15
One of the best of the northern sky's globular cluster is 31,000 light years away. Although visible in binoculars as a nebulous patch, in a telescope it is a real showpiece. It contains about 100,000 stars and is about 130 light years in diameter and is about 6th magnitude. Many of these stars may predate the Milky Way.

Perseus

M34
This bright, 5th magnitude open cluster sits in the middle of a rich field of stars. It is an interesting view through binoculars or a telescope. It contains about 80 stars and lies about 1,500 light years away.

Double cluster - NGC 869 and 884
Two of the finest examples of open clusters in the sky, are magnificent through binoculars or the low power field in a small telescope. They are at a distance of about 7,400 light years away. Beside the double cluster there are 6 other clusters that are visible in binoculars. Have you spotted them yet?

Puppis

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M93
This dim glow of 6th magnitude appears as a small ball of celestial cotton. Under dark sky and steadily held binoculars a few points of light within it should be revealed

Xi Puppis
A bright 3.5 magnitude star looks like a brilliant topaz amid countless fainter sapphires. It is a wide binocular double; the 5.3 magnitude companion is to the southwest.

M46 and M47
These two open clusters are only about 1 degree apart and in a part of the sky where there are not any bright stars which makes them difficult to find. M47 is magnitude 4.4 which indicates naked eye visible. Good hunting.

Collinder 135
This cluster contains brighter stars and contains the 2.7 magnitude ruddy star, Pi Puppis.

Sagittarius

Sagittarius contains more Messier objects than any other constellation. The best way to identify them is to take them one by one. The beginner will have to be careful not to confuse the various objects.

The principal stars of Sagittarius form the famous “Teapot” asterism. The brightest part of the Milky Way seems to emerge from the Teapot's spout like a puff of steam.

M22
The Great Sagittarius star cluster is a very large globular -- the best of the constellation's many globulars. At magnitude 5.1 it is an easy binocular object, but a telescope really brings out the cluster's beauty. Only 9,600 light years away, it is one of the closest globular clusters. It contains about 75,000 stars and is about 50 light years in diameter.

M23
Just one of the many clusters in Sagittarius. M23 presents over 100 stars in an area about the size of the Moon. It is a striking sight in binoculars or in a telescope at low magnification. M23 is about 2,000 light years away.

Lagoon Nebula - M8
On a dark night this is visible with the naked eye just north of the richest part of the Sagittarius Milky Way. This 6th magnitude nebula lies about 5,200 light years away.

Trifid Nebula - M20
Found only 1 ½ degrees northwest of the Lagoon Nebula. This is smaller and fainter than other nebulae and may be a bit of a challenge in binoculars, though is easy in a 6-inch telescope. Ideal conditions and sharp eyes might detect M21, which is located just ½ degree northeast of M20, although it is rather faint by binocular standards.

Omega Nebula - M17
Also called the Swan, the Horseshoe or the Checkmark, this nebula can be seen clearly in binoculars. The length of the nebula is about 12 light years and the diameter is 40 light years. It's about 5,700 light years away.

Scorpius

Antares
The Heart of the Scorpion, this red giant is about 600 million miles across and 9,000 times more luminous than the sun. It is thought to be about 520 light years away. Antares has a green companion star which is a radio source, but it is not visible with binoculars.

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M4
Binoculars show this globular cluster as a fuzzy patch while a small telescope will start to show individual stars in a haze. This cluster is one of the nearest and largest of its kind. It lies about 7,000 light away and contains about 10,000 stars when looking to 19^{th} magnitude.

M6 - Butterfly Cluster
This large open cluster of about 50 stars resembles a butterfly. It is about 2,000 light years away.

M7
This large, bright open cluster, lying south east of M6, needs to be seen through binoculars to be fully appreciated. M7 lies 800 light years away.

NGC 6231
This bright open cluster lies in a rich region of the Milky Way. It is best surveyed in binoculars or at very low power in a telescope. In this same area of the scorpion's tail are several other binocular-visible objects. Can you find NGC 6322, NGC 6242, NGC 6281, NGC 6393, or the clusters Harvard 12 or Harvard 18? Happy hunting!

M80
This small, bright globular cluster can be seen in binoculars but needs a 10-inch telescope to resolve stars.

Scutum

Wild Duck Cluster - M11
This magnificent cluster can be seen without optical aid as a bright patch of light. It contains more than 600 stars and is approximately 5,500 light years away. It is one of the finest open clusters in the sky, and should be viewed through a telescope to be fully appreciated.

Serpens

M 5
One of the greatest shows of the summer sky, this very striking globular cluster is about 26,000 light years away and contains at least 500,000 stars.

Eagle Nebula - M16
This cluster of about 100 stars also has an emission nebula surrounding it. This is 6^{th} magnitude but a telescope is needed to see it well. It is about 8,000 light years away.

Taurus

The Pleiades - M45
Also known as *The Seven Sisters*, it is the most famous star clusters in the sky. On a reasonably dark night you should be able to see at least six of the stars in the Pleiades with the naked eye. Containing more than 500 stars in all, the Pleiades is about 410 light years away and covers an area four times the size of a full moon. It is best seen with binoculars.

The Hyades
Like the Pleiades, this is also an open cluster, but it is so close to us (only about 150 light years away), even when viewed with the naked eye the stars seem to be spread out. Lots of color can be seen as the individual stars are studied. Can you pick the differences out? Try enhancing the colors by slightly defocusing your binoculars.

Aldebaran
This is an orange giant and is the brightest star in Taurus. Only 68 light years away, it marks the eye of the bull on some star charts.

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Crab Nebula - M1

At magnitude 8 this can be very difficult to find. It is worth finding however since it is one of the most unusual objects in the sky. The distance is 6,300 light years.

Triangulum

The Pinwheel Galaxy - M33

This galaxy is one of the brightest and biggest members of the Local Group. The magnitude is 5.5 but its light is spread out over such a large area that it is difficult to see. Although it can be seen with the naked eye on very clear nights, you need a dark sky and binoculars to see a fuzzy glow. The Pinwheel Galaxy is 2.3 million light years away, slightly farther than the Great Galaxy in Andromeda even though it is only 570,000 light years away from M31.

NGC 604

A tiny, fuzzy patch on the Northeast side of M 33 may be found in larger binoculars by those with sharp eyes. One of many diffuse nebulae in M33, NGC 604 is about 30 times larger in diameter than M42, the Great Nebula in Orion.

Ursa Major

Dubhe

This bright, 1.8 magnitude star has been named as Utah's centennial star being 100 light years away.

Mizar and Alcor – "Horse and Rider"

This famous apparent double star in the middle of the dipper's handle is separated by 12 arc minutes and is possible to be seen as a pair with the naked eye. Mizar is itself a true binary star separated by 14 arc seconds.

M81 and M 82

This spiral galaxy pair can be easily seen with binoculars, even when viewing in a city, and is very dramatic when viewed under good conditions. M 82, at 8.4 magnitude, is a long, thin galaxy just a ½ degree from M 81, magnitude 6.8 and is a lot more difficult to see with binoculars. These two galaxies are about 7,000,000 light years away.

Ursa Minor

Polaris

Polaris viewed with binoculars or a low powered telescope shows a small circle of stars known as the "Engagement Ring of Polaris", Polaris being the diamond in the Ring.

Virgo

The Realm of the Galaxies

M49, M84, M86, and M87 are some of the objects that might be found in this area of the sky with binoculars. Scattered throughout Virgo and Coma Berenices are more than 13,000 galaxies known as the Virgo Cluster or Coma-Virgo Cluster, this mighty club of distant systems of stars are worth looking at with a small, wide-field telescope on a dark night.

Vulpecula

Dumbbell Nebula - M27

This is one of the finest planetary nebula, superbly seen in small telescopes. Being 7^{th} magnitude, it can be found with binoculars, but appears only as a faint nebulous spot. It measures nearly 2 ½ light years in diameter and is about 980 light years from us. This is locally known as the Wiggins' Nebula.

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Coat Hanger - Brocchi's cluster - C 399

A very loose cluster that looks like a wooden coat hanger made up of 6 stars forming the crossbar and four more forming an upside-down hook. These are 5^{th} to 7^{th} magnitude stars, and can be found about half-way between Vega and Altair (stars forming two corners of the Summer Triangle) in the dark area where the Milky Way splits. There are about 30 total stars in this cluster and it lies about 425 light years away.

This list is by no means comprehensive! It does not include many of the double and variable stars that are also visible with binoculars. Once you become adept at using binoculars, share your discoveries and enthusiasm with your neighbors and friends who may not realize what can be seen in the sky with their closet-bound, often neglected binoculars.

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Part 5. Lesson Ideas and Activities

5.1 Introduction

I've divided the approach to astronomy into two parts: Observational and Rainy-Night. The hope is that the two parts complement one another and open doors to our friendly neighborhood starry dynamo. It's easy for me to loose track of living in a small corner of a pretty interesting universe, but every so often I get out on a clear night… as 'Dr. Arroway' says in *Contact*, "I had no idea." This sends me back to the books, and I bounce between the two and so feel lucky to have come along after so much has been figured out and written down.

From my point of view there are a bunch of profound concepts in astronomy that are easy to grasp in the moment but harder to hold on to.

Scale: The physical processes span all distance magnitudes
- atoms of hydrogen
- the light spectrum
- micro-meteors that rain down on the earth
- coal-black grit covering an Apollo astronaut's space suit
- the height of a 5th grader
- the city-sized moons of mars, escapees from the asteroid belt
- the distance from Alexandria to Athens
- Jupiter's moons, larger than Mercury
- the earth
- Saturn from ear to ear
- our solar system
- six years at the speed of light to a nearby star
- the hundred billion stars in this galaxy 100,000 light years across
- 2.5 million light years to the galaxy in Andromeda
- ten billion light years to the edge of the universe.

Time, for example intervals in the 'life-history' of a light particle.
- the billionth of a second it takes hydrogen atoms to fuse into an atom of helium at the center of our sun, releasing energy in the form of light.
- the million years (or perhaps only 50,000) it takes that light particle to travel like a pinball from the center of the sun to its outer edge.
- At the end of this journey that light particle flies across space for 8 minutes to ricochet off a rock on the moon and vanish after another half second into your eye.

This is an improbable series of events, but take a glance for one second at the moon and a million such light particles fall into your eye, each with that very history.

A list of 'actors'.
- Stars
- Constellations

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- mythical characters and stories
- black holes
- spinning neutron stars, white dwarfs, red giants
- globular clusters and open clusters
- nebulas, bands of dust, supernova remnants, the cosmic junkyard
- dark matter… what the heck is dark matter???
- the earth with its gravitational and magnetic fields
- the solar wind feeding the aurora borealis
- the asteroid belt occasionally sending us killer meteors
- the Oort cloud occasionally sending us killer comets (dis – asters)
- Dinosaurs who never knew what hit them.

The forces that animate everything

- electromagnetism
- gravity
- the strong force that prevents atomic nuclei from self destructing.

These ideas—time, space, celestial objects, our attempts to make sense of them, and the forces that drive them—are our working bag of goods.

General Plan

This document came about as a result of repeated attempts to go outside and look up at the stars. We were inevitably thwarted by cloudy rainy wet cold miserable nights with lightning striking everywhere around us and wild boars charging at us out of the trees and police helicopters circling overhead and anyway we had skipped lunch and were hungry and we were wearing scratchy wool sweaters. It is no fun to be thwarted, clouds in particular, so we decided that if we can't Observe we can at least run around inside.

This document proceeds in four sections after this introduction. It's a work-in-progress.

- Rainy Night Astronomy.
- Observational Astronomy.
- Astronomy Basics.
- References.

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5.2 Rainy Night Astronomy

General Ideas For A Rainy Night Indoor Session

The following is a dialog (with questions to students) that I've done a few times. The objective is to point out and hopefully undermine the distinctions between "scientist", "explorer" and "person". My ulterior motive is to encourage students to think of themselves as scientists and explorers. There are some other key ideas as well, summarized at the end of this section.

Moderator: "**Imagine** being sent to a completely new world…
You wind up there, maybe the journey takes you a long time, almost a year, and you don't understand anything that's going on. You don't recognize the life, you don't know about the creatures that live there, you don't understand their language, or their customs, or what is safe to eat or anything.

You're in a pretty tough spot.

Now think back in your minds to what you know about history. Can you think of any person who was in this kind of situation, a famous person, a scientist, or an explorer, who had to start from scratch and figure everything out like it was completely new?

[pause; guesses; example a student guesses "Columbus" and I'll say something like "Christopher Columbus is a good guess, but that's not the person I have in mind." This goes on for awhile and then I usually turn to one of the girls and ask her name. Suppose it is "Ashley". I turn back to the class and say:]

Actually the person I have in mind is Ashley. She showed up here on this planet about 10 years ago and for the past 10 years has figured out
Survival
Language
Mathematics
Social Customs
And the laws of physics.

In fact every one of us has had to figure out the same thing... does that make us some pretty amazing scientists or what?

There are lots of ways to continue, including the following. The second point in this flow of ideas is to emphasize that curiosity is a useful tool.

(Your job right now is to figure out what I am doing next...) Now, I mentioned that we're standing on a planet. What shape is it? [sphere] How do you know? [pictures] What if somebody is just playing a joke??? Is this "sphere" fixed in space or is it moving??? Does it spin? How long does it take to spin around once? How do you know it's spinning? What's the big bright thing in the sky? How far away is it? How do we know how far away it is? How bout the bright thing in the night sky?

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Ok, so have you figured out what I'm doing? (Remember this was your job, although you probably forgot and thought your job was to answer my questions.) [Pause for chance to evaluate 'what I was doing'.]

I'm being curious. Or at least obnoxious. Curiosity is one of the two most powerful tools that you all have as scientists. So now maybe let's make it your turn; do you have any questions about the stars or the planets or galaxies? <open questions 10 or 15 minutes>

Ok, so to review: You are all excellent scientists, and you have two powerful tools: Curiosity and the second tool is… ? [guesses] The second tool that I have in mind (there may be others) is your imagination. <go from here into the play, or the solar system, or the life of a star, or wherever.>

It is also possible to play this rhetorical game with the question "Why do we do science?" The answer to this question is usually completely non-obvious, and students will try and supply their idea of "proper" answers having to do with understanding nature or making some sort of progress. Which of course is all well and good but certainly not why I do science.

Summary of the Opening Dialog is
1. Students are already good scientists.
2. We have two very powerful tools: Curiosity and Imagination.
3. We do science because its really really fun.

Messier Catalog
Basic idea here is to lay out a tiling of white cards, some of which have photos on the backs. The tiling of course represents part of the sky, and there are stars drawn in to match a star chart, but with no constellation lines. Probably use the Sky Atlas, include coordinates. The idea is to describe a Messier object (galaxy, globular cluster, open cluster), then describe its location, and have the students aim their 'telescope' at the proper part of the tiling. If they do it correctly, when they flip over the tile there is the photo of the Messier object.

This is an approximation of feature hunting that one does with a telescope. I like the general principle here but I think this needs some more thought. The payoff is pretty simple; a picture of a deep space object, and the activity is rather cerebral, not too physical, so it would be geared towards older students. However if your payoff object is a galaxy then this activity opens the way to talking about looking out of our galaxy and seeing other galaxies. This in turn could lead to looking at some of the incredible Hubble Space Telescope pictures of galaxy swarms.

Phases of the Moon
The goal is to show the geometrical relationship between the sun, moon, and earth, but without (necessarily) the idea of the earth going around the sun. We just concentrate on the moon's orbit and how this produces phases of the moon.

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Materials
Large styrofoam ball, stick
2 Moon Pictures (Near side, far side), with labels
Black magic marker
Small spacecraft on a stick
Single light source (bare bulb is fine)
Book New Moon

Plan
Move to a room that can be made pretty dark, turn on the lamp (sun).
Relate: Distance, size of the moon relative to earth
Explain the Weird Thing about the moon: One face towards us.
Label Near and Far
Optional: look at the moon photos, draw a feature or two.
Set up the orbiting moon and watch it's phase as it goes around the earth.

Questions
Why does the moon look different over the course of one month?
Is one side of the moon always dark?
Is it always the same side?
How do we know what the far side of the moon looks like?

Key Concepts
1. One side of the moon always faces earth
2. Moon goes around earth once per month (moonth)
3. Moon phases are due to solar illumination

Advanced concepts
1. Earthshine
2. Eclipses are rare because of the inclination of the moon's orbit relative to the ecliptic
3. Tides

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Constellation Stories
This activity is pretty simple to do and potentially a really excellent learning experience.

The objective here is to show that space has depth and to engage the kids in creation of their own constellation myths. Set up a 3-D mobile which, when viewed from one direction, shows a well-known constellation.. Note that the depths of the stars do not have to be realistic, they just have to give an approximation of the constellations when seen from one view and an interesting star pattern when seen from another.

The objective here is to show that space has depth and to engage the kids in creation of their own constellation myths.

The big dipper (asterism) or the big bear (Ursa Major) makes a good subject. See the Field Guide for background mythology. One could read this as an example of myths/stories.

Then "Suppose we live on Arcturus, in Bootes..." Move to the oblique location; re-view the constellation from a different point of view and generate an alien's myth. Can leave a star in the old position to represent the earth's sun, this can become part of the new constellation.

Construction Details
One person is designated the Constellation Builder (and should have an assistant) and the main group of students are the Constellation Managers.

Many classrooms have little perforated tiles in the ceiling which are ideal for stick-pins. Suppose you have ten small ping-pong or Styrofoam balls with thread attached to them, e.g. with tape or threaded through with a needle and secured. The other end of the thread can be wound around a stick-pin and the Constellation Builder can climb up on a desk or ladder or chair to reach the ceiling, push in the pin, and tie off the thread. The length of the thread will be adjusted, so the Builder has to keep this in mind.

This would be a good time to suggest that the Constellation Builder be an adult who is being careful not to fall. Meanwhile the Constellation Managers, the students, have a picture of the intended constellation or asterism and are clustered together on the "earth", i.e. with all their heads in one location as much as possible so they all have the same perspective. One way to do this would be to hang a Styro-ball representing the earth; the Managers must then site from that ball.

The construction proceeds as a collaboration: The Builder places Styrofoam balls and the Managers tell her whether they need to move up or down or left or right. It will take maybe 15 minutes (with a little advance prep of strings and balls and stick pins) to get the thing looking right.

Here's the trick: While the Builder has been putting in the Stryro-balls, adjusting the up/down and left/right positions, she has also been quietly varying their location along

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the third axis, front/back. In this way the resulting stars do not hang in a plane, but form a 3-D mobile. Another consideration is making them heavy enough to hang fairly stable; maybe in a breezy location it would be necessary to use golfballs.

Incidentally if one were to try and do the constellation of Perseus, one could "black out" half of Algol with a Sharpie and then set it spinning/twisting to simulate a variable star. Of course Algol is actually an eclipsing binary but this would be a little tricky to model more precisely using multiple balls on the scale of this Mobile.

Once the thing "looks right" from the earth, the students are ready to view it from another point in space (perhaps hang a second perspective ball) and from here they can proceed to making up their own constellation and myth.

Since we are examining spatial relativism with this activity, a branch-off could easily lead to the idea of cultural relativism as well. If we are not Greeks but rather Navaho or Chinese, what might we make of this particular constellation?

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Constellation Stories 2: Mythological Play

To make this script easier for the narrator to read it is suggested to print it out in 16-pt font.

Advance Prep:
Make Constellation Cards
Divide students among this character list:

- Mom/Dad/7 Sisters of the Pleiades (CONST)
- Villagers (at least 4) who get dragged out to sea by
- Cetus, a nasty sea monster (CONST)
- Gorgon (up to 7, must include the mortal Medusa)
- Perseus the hero (CONST)
- Cassiopeia, who is not amused (CONST)
- Cepheus, her husband who says Yes Dear (CONST)
- Andromeda, their daughter the princess (CONST)
- Pegasus, a winged horse (CONST)

The ones listed with (CONST) get a constellation drawn on the 3x5 card. One card per character will suffice (they share) or you can make extras which is a little nicer for the students.

Each constellation card has:
Name, diagram of Constellation
Line of dialog ("Yes dear.")

The only character whose dialog changes is the villagers. Their initial line is "Wow those Pleiades sisters sure are beautiful." They later add "…but the queen is more beautiful still" and later scrap all that in favor of "HELP!!!"

Also the Pleiades are only in the beginning of the story, so their lines are cued directly by the narrator (no card).

In the script, the notation <> means the narrator cues the character to speak their line. Cues and so on are given in (parentheses).

Scene: Large empty room bisected by a shoreline made of string, the shore of ancient Aethiopia somewhere in Greece. Story proceeds with a narrator/director who may or may not claim to be Zeus. The students are obliged to stand on their knees which improves line of sight and cuts down on unnecessary improvised motion.

Narrator:
Once upon a time there was a Greek god named ... Zeus, who was angry all the time. Just like me. (Pretend to be angry.)

By the way if you are not acting, then you are In Tableau which is like freeze tag, perfectly still and silent. Tableau!

Now one thing you have to understand is that people were always bugging Zeus, and that would give him a headache, so usually he would just put them up in the sky out of the way so they couldn't bug him anymore. You had to be careful.

And once long ago, living on an island, there was a family: A mother named Pleione who always said 'Behave!' <> A father named Atlas who always said 'Ow my aching back!' <> and 7 Sisters (pause while laughing subsides), named Alcyone Merope Celaeno Asterope Electra Taygete and Maia. Who were very beautiful. Especially Maia.

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(If you happen to own a dog named Maia you can have the children being the Pleiades hold her while this part of the play unfolds. But eventually put her outside because she is probably pretty charming and will pull too much focus.)

And there was a hunter named Orion who was always chasing them, and they complained about this to Zeus until he got a headache, and you guessed it, he put them all up in the sky, including Orion. But even up in the sky the Pleiades were still very beautiful. I didn't tell you this but the name of this family with the seven sisters is the Pleiades.

And on the shores of the kingdom of Aethiopia, there lived a queen named Cassiopeia who always said 'We are not amused.' <> And her milquetoast husband the king Cepheus who always said 'Yes Dear' <> (both:) <> <>

Now the villagers, who had nothing better to do than look up into the sky at night, because they had no TV, always marveled at how beautiful the Pleiades were. So they always said 'Wow those Pleiades sisters sure are beautiful.' <> And eventually Queen Cassiopeia heard this and she said <>. And the king said <>. And this went on for quite awhile. <> <> <>. One day Q. Cass issued an edict, that she was to be the MOST beautiful person in the world. From then on, the villagers could say <> but they had to then say 'But Queen Cass is more beautiful still.' <> <>. The king still just said <>.

Now somewhere else in ancient Greece there lived a 7-headed monster called the Gorgon. And it snarled and hissed and made disgusting sounds <>. Which of you is Medusa? Ok, only one of you is Medusa, and unlike the rest, she can be killed. She is mortal. And on a dare the great Warrior Hero Perseus--who could fly--flew to where the Gorgon lived in a cave and began to do battle. He always said 'Have At Ye' and waved a sword and a shiny shield.

<> <> <>

But he knew that if he looked at the Gorgon, then he would be turned to stone, so he had to do battle while looking the other way.

<> <> <>

Tableau. We will leave Perseus and the Medusa locked in mortal combat for awhile.

Now Zeus heard all about Queen Cass and her edict, and decided to punish her for being so vain. So he sent the Sea Monster Cetus, who always said 'I'm HUNGRY' <> to munch on the villagers that lived on the shores of Aethiopia. So on Monday Cetus came up out of the sea <> and dragged off and ate a villager. And no longer did the villagers talk about how pretty the Pleiades were. All they could say now was 'HELP!!!' <> And the Queen said <> and the king said <>.

ok, settle down.

Now the next day the same thing happened.
(Cue: Cetus, villagers, drag, death, queen, king)

Meanwhile Perseus was still doing battle with the Gorgon <> <>. (Allow the battle to rage a bit longer.) Tableau.

And on the third day, yes, you guessed it.
(Cue: Cetus, villagers, drag, death, queen, king)

Now Queen Cass knew that she had to do something. Something BIG! To stop Cetus from eating every person in her kingdom. So she took her daughter Andromeda, who always said 'I don't deserve this.' <> (Andromeda's delivery can be coached as 'what a ripoff', kinda whiny.) And the queen chained Andromeda to a rock by the seashore so that the Sea Monster, who always said <>, would gobble her up.

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And again Andromeda said <> Queen Cass thought that after her daughter got gobbled up, Zeus would think that the Queen had suffered enough and he would send the Sea Monster away.

Meanwhile Perseus who always said <> held up his shiny shield to the face of Medusa, and she caught her own reflection in it and so she turned herself to stone because she was so ugly. Then he chopped off her head (without looking at it) and put it under his shoulder and flew back across the sea back towards home.

And as he approached the shores of Aethiopia, he saw the lovely Andromeda who always says <> chained to a rock by the shore just as the giant sea monster Cetus came up out of the water and said <>.

Thinking quickly, Perseus held up the head of Medusa towards the sea monster, and as it glanced up, it turned to stone, Tableau! And at this very moment some drops of blood fell from Medusa's head into the pounding surf.

Now do you know what you get when you mix Medusa's blood with waves crashing against the shore? (Pause for guesses.)

Yes, that's right, Medusa blood plus crashing waves always produces a fantastical magical winged horse named Pegasus who flies up into the sky and says "Hey, I'm a winged horse!" So Pegasus leapt up into the sky, and said <> Tableau!

And then Zeus came by and made his famous speech.

What Zeus said:
Let's see.
We have Queen Cass <>
and her husband the king Cepheus <>
and some terrified villagers <>
and Pegasus <>
and a stone sea monster who can no longer say <>
and a Princess who thinks <>
And a returning Hero Perseus <>
And this has given me a HUGE headache.

So guess where *you're ALL going*. Now kids will look up in the sky and see you there and think 'Boy what a bunch of goofballs.'

[Note: If there is an observation opportunity to see the Andromeda galaxy, then one could add something about Zeus giving her that galaxy for example as a necklace.]

And that's exactly what Zeus did. So kids two thousand years ago could look up into the night sky and think 'What a bunch of goofballs.' And that's what you have in common with them, because that's what you get to do this week. For thousands of years people will still repeat these stories, and in this way the stars we can see at night connect us with the past and the future of our own goofball human race.

Your job is now to go outside and see if you can find these constellations. You're already excellent scientists, and that's good news because it means you can learn about anything you want to learn about.

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Build The Solar System

The idea is to use spacecraft photos to create a spatial-relationship montage of all the major bodies in the solar system. One idea: Give the photos without labels, just a series of clues. After they've done this, they do the distance-scale visualization with pin-heads and so on.

Photos currently 'in the box':

- Sun
- Mercury (composite)
- Venus (optical and radar)
- Earth (Gal. flyby w/ Antarctica)
- Moon
- Mars
- Deimos
- Phobos
- Asteroid
- Jupiter
- Europa
- Callisto
- Ganymede
- Io
- Saturn
- Titan
- Other Saturnian moons
- Uranus
    - (moons)
- Neptune
- Pluto

Put together the pictures to make an accurate picture of our solar system. Below are some clues to help you. Lay the photos on the floor and rearrange them until you're happy that you've gotten close to accurate. Place the sun first, then the planets going away from the sun in the right order, then the moons around the planets.

1. The Red Planet is a nickname for _________.
2. In between the Red Planet and the largest planet is the asteroid belt.
3. The two moons of the red planet are very small and look like asteroids.
4. We have a picture of the asteroid Gaspra etc.
5. The closest moon to Jupiter has active volcanoes on it.
6. The largest moon in the solar system orbits Saturn.
7. The letters for the planets are MVEMJSUNP, from the sun going away.
8. The picture of mercury is actually a lot of smaller pictures glued together at the edges.
9. Our moon looks a lot like mercury, but <size>
10. Jupiter has at least 8 moons, but you only have pictures of the 4 largest: Callisto, Ganymede, Europa, and Io.

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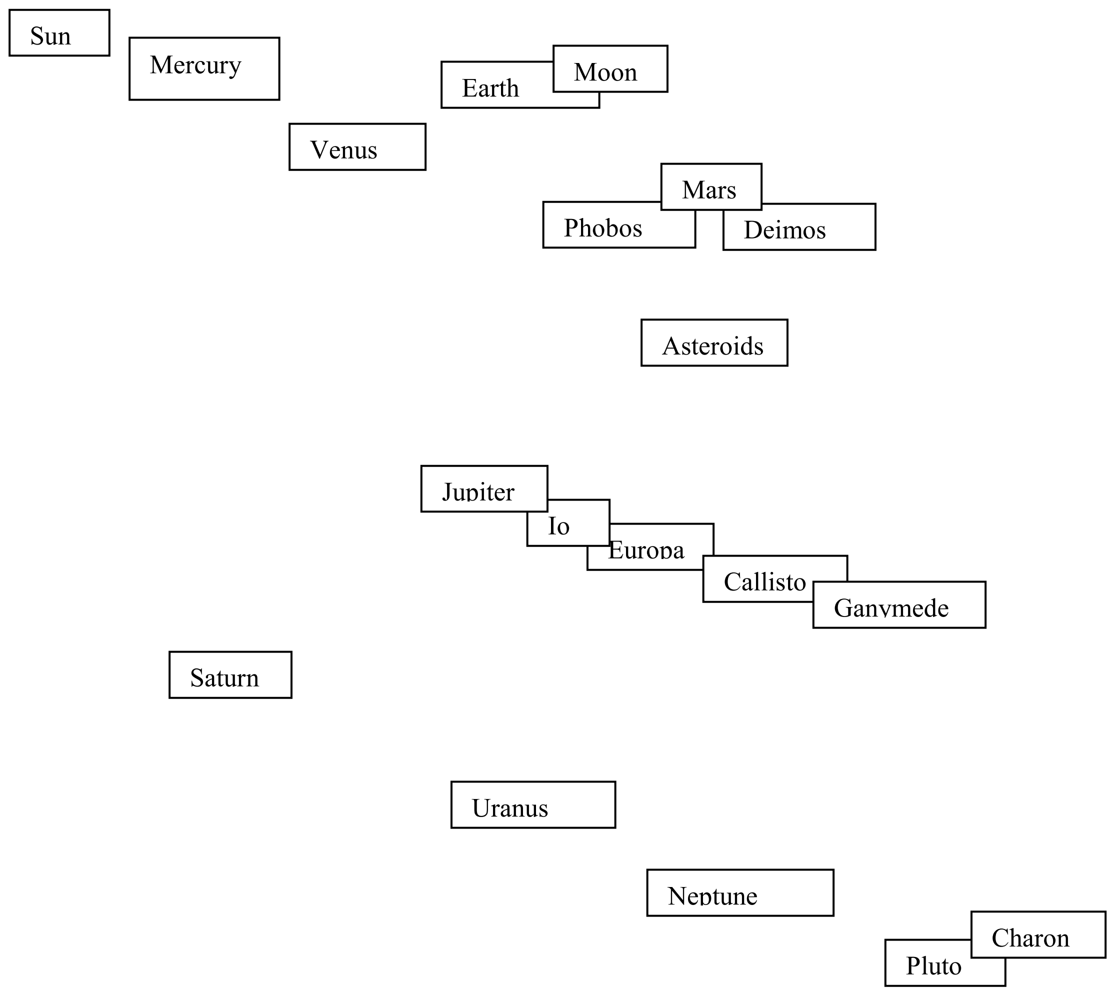
Now that you have the pictures in place, flip them over to see how you did. They should match this scheme:



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Don't Just Build It, BE the Entire Solar System

This is the solar system project done dynamically, using live bodies. We should have four students for the sun, with flashlights. We are trying to get to a tableau, and then Motion! Every student also needs a mantra. Mercury is almost a one-face, two students, one says "Ouch I'm hot", the other says 'Brr I'm freezing', etcetera. Everyone watches Mercury get set up, we invite Mercury to take one orbit (at arms length) around the sun, saying her mantra, then freeze, add Venus, etcetera. No Martian moons, but Jupiter we can give four moons to, Saturn gets Titan, and add in the last 3 planets gets us up to 16 students. Outer planets only get to take a step after Mercury makes 4/6/8 orbits. Leave a gap between Mars and Jupiter for asteroids, and as the moment to launch into motion comes, boombox Holst's Jupiter, turn this into a big pseudo-choreographed dance.

Life of a star (placeholder; needs more notes)

This is a similar notion to the Living Solar System, only now all the kids represent hydrogen gas atoms. They mill around for awhile and are eventually given instructions by the lead person. Early on the main instruction will be "Take a step towards everyone else in the room" with an explanation about gravity. Eventually our star will ignite, then it will burn for a long time, then it will go supernova, collapse, finally into a black hole.

Building a Comet (needs more notes)

Windex: Ammonia
Dry Ice: Frozen carbon dioxide (really!)
Liquid water (will freeze when mixed in)
Dirt (inorganic molecules; minerals)
Corn syrup or other organic molecules.

Pound the dry ice into dust (put in cloth bag, use a big rock)
Pour it into a mixing bowl.
Add windex, dirt, corn syrup.
Add water, mix it all together.
Put under a heat lamp to produce accelerate melting, jets.

Grab some dry ice with a pair of vice grips and squeeze.

There is a deep idea buried in comets: To this very day they are considered harbingers of doom, inspire considerable fear. But careful observing and careful thought over centuries has empowered us with respect to comets. We now know:

- Where they come from.
- What they are made of.
- How big they are
- Why they have tails.
- What the sun does to them.
- Whether or not they are going to come close to or hit the earth.

And we are learning more about them all the time.

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5.3 Observational Astronomy

Going Outside and Looking Up

Supplies

- Flashlights, red cellophane, rubber bands
- Sky charts
- Binoculars
- Warm clothes

Observing Sun Spots (Rob scammed off some web site; Rob needs to *do* this.)

Materials:

1. binoculars
2. white paper
3. masking tape

The sun is a medium sized star. The Earth orbits the sun by the force of gravity. The sun is comprised of about 3/4 hydrogen and 1/4 helium, along with other elements. The sun is made of different layers. The center, like Earth's, is called the core; the core is also called the nuclear reaction zone. The next layer is called the radiation zone, then the convection zone. Outside of the convection zone is the first of the three layers of the sun's atmosphere, the photosphere. The next layer is the chromosphere, which is only visible from Earth during a solar eclipse. The outermost layer is the corona, and like the chromosphere, is only visible during a total solar eclipse. The photosphere is the layer we see and is the layer in which sunspots can be seen from Earth. Galileo studied sunspots in 1612. Since Galileo, scientists have continued to study sun spots and believe they are caused by magnetic activity.

Facts about the sun:

- ❖ Light from the sun takes about 8 minutes to reach the Earth.
- ❖ The distance between Earth and the sun is 92.9 million miles (149.6 million km).
- ❖ The diameter of the sun is 864,950 miles (1,392,000 km).
- ❖ It takes the sun 25.4 days to rotate once.
- ❖ The temperature at the surface of the sun is (5,500 degrees C).
- ❖ The temperature at the center of the sun is (15,000,000 C.)
- ❖ The age of the sun is about 5 billion years old.

Procedures:
**********CAUTION the students to never look at the sun ************
When outside:
Cover one side of the binoculars with tape.
Place the paper on the ground outside, the flatter the surface, the better.
Hold the binoculars about 12 inches from the paper.
Focus the image of the sun on the paper.
The sunspots should appear as dark spots.

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