Massachusetts Institute of Technology
Department of Earth, Atmospheric, and Planetary Sciences
12.409 Observing Stars and Planets, Spring 2002

Handout 6 / week of 2002 February 25

Observing Tips

Vision

Dark adaptation

Dark adaptation takes time. The eye's pupil expands to its maximum diameter in seconds after the lights go out. The main cause of dark adaptation, however, is chemical and not related to the size of the pupil. After going from light to dark our eyes gain in sensitivity due to the release of a chemical called rhodopsin that acts to bleach the photopigments in the cells in the retina.. The retina contains two main types of cells, rods and cones. The rods are distributed over the entire retina, are sensitive to lower light levels, and are insensitive to red light. In contrast, the cones are clustered towards the center of the optical axis, are sensitive to bright light, and have three types each of which are sensitive to red, green, or blue wavelengths. Over the first 5-10 minutes in the dark, the cones reach their maximum level of dark adaptation. This allows the general sense that one is dark adapted. But over the next 20-40 minutes the rods will asymptotically approach their sensitivity limit and during this time period the eye can gain 2 or more magnitudes of sensitivity (how much fainter is this…by what factor in intensity? Hint: see handout 4). Using a red flashlight will help protect your night vision because the rods that are most sensitive at low light levels after dark adaptation are not sensitive to red light.

Averted vision

Averted vision (placing your target object away from the center of your eye's FOV by say 8°-16°) can help you see very faint objects. The reason for this is that the cones (sensitive to bright light) are centrally located creating somewhat of a blind spot to very dim objects whereas the rods (sensitive to lower light levels especially after dark adaptation) are distributed over the entire retina.

Color

Faint, deep-sky objects often disappoint beginning observers due to the lack of brilliant color as seen in the published imaging results. The reason for this is again due to the physical nature of our natural detector. Remember that only the cones are sensitive to color. Unfortunately, they are also insensitive to low light levels compared to the rods. Thus at low light levels we are using just our rods and making black and white detections. M42 is one of the only nebulae with high enough surface brightness to stimulate at least some people's cone cells (this varies greatly from person to person).

Eye glasses

Many who wear eyeglasses find it difficult to properly position their eye for viewing with an eyepiece; the amount of difficulty varies somewhat with eyepiece design. There's also a problem of unwanted reflections of your eye and lights in the observing environment. The solution is to remove your glasses and then adjust the focus for your now uncorrected eye; you and your partner (and probably your instructor and UTA) will thus each prefer slightly different focus settings (this works if your glasses correct primarily for nearsightedness or farsightedness; if you're severely astigmatic you're sort of stuck with viewing with your glasses on although you should try it both ways to see which is better for you).

Miscellaneous

- Use the moon filter to cut down the uncomfortable intensity from the full Moon
- Views through finderscope and main scope without the diagonal are inverted. The view through the diagonal is left-right reversed but not inverted. Explanation of this is left until handout 7 on optics and telescope design.

Star Hopping

Star hopping is analogous to looking at a map and jotting down some directions to follow while you're driving but you also want to include some picture of landmarks so you know you're on the right track. **Sufficient planning before an evening of observing can greatly decrease your frustration level when searching for faint fuzzies**.

The following is an example of a well prepared set of directions to find NGC 2392 (a planetary nebula ~8 mag that would count as an intermediate object in the menu). In order to proceed you will need a Star atlas (preferable Norton's) and the atlas overlays from the Atlas Supplement notebooks.

1. Find Castor and Pollux (bright stars in Gemini) in the Atlas.
2. Center the finderscope overlay on Pollux (aka β Geminorum).
3. Note the triangle formed by Pollux, σ Geminorum (to the northwest), and υ Geminorum (near the southwest edge of the field).
4. Move the overlay so it is now centered on υ Geminorum (this corresponds to your first telescope movement).
5. Note the two new pairs of stars (64, 65 and ι Geminorum, 59) that have entered from the west of the field.
6. Move the overlay so it is centered on ι Geminorum (the fainter 59 just to the southwest will confirm you have the right star at the telescope…you might need to check your eyepiece).
7. Note 57 at the south edge of the field.
8. Move the overlay so that it is centered on 57.
9. Now the fairly bright star, δ Geminorum, should be just out of the FOV to the south (in the same direction you moved from ι Geminorum to57).
10. Move the overlay to the south and then center on δ Geminorum.
11. Note the equilateral triangle formed by δ Geminorum, and 56 and 63 (to its southeast).
12. Note the two faint stars on either side of 63 (this will confirm you have 63 in your eyepiece at the telescope).
13. Note the flat triangle that 61 and 63 form with our target NGC 2392.
14. Center (or put it at the sweet spot if your finder is a bit mis-aligned) the finderscope on the position of NGC 2392 in the triangle (you will not be able to see it in the finder).

A word about directions: Notice that in a star atlas, east is left of north (opposite to land maps). If you need to convince yourself of this remember that RA increases to the east. Next remember that north is up on your map but in the sky it is the direction pointing to Polaris (sometimes it helps to turn your map accordingly when you are outside at the telescope).

At the telescope: Before you attempt to locate the object, figure out which way is N,S, E, and W when looking through your finder (and do the same for your eyepiece if you are using the diagonal). Move the telescope N (using the N button) and stars will enter from the North edge of the field. Do the same for E-W and you're ready to go.

If you get lost, start over from the beginning of the process rather than attempting to figure it our on the fly…this will only lead to frustration.

The following is an article from Sky and Telescope "Backyard Astronomy" from Feb. 1984, pp. 131-133.

Backyard Astronomy – 4 / Conducted by Alan MacRobert

The Art of Using a Telescope

ONE OF THE MOST fun parts of being an amateur astronomer is showing off the heavens to others. The "oohs" and "aahs" at a public star party as people get their first good look at the Moon or Saturn are a pleasant reward for the proud telescope owner. Naturally, he or she will have chosen the most spectacular object above the horizon. Sometimes there is a temptation to show people more typical objects — ghostly, barely visible apparitions with obscure catalogue numbers — "to give them an idea of *real* astronomy." The reactions then are not so encouraging, even when the viewers are told they are looking at a recently recovered comet or a galaxy 40 million light-years away.

The truth is, most of the thousands of objects visible in amateur instruments are not the least bit spectacular. Anyone who gets a telescope for visual thrills may soon be disappointed.

The riches a telescope offers are of a different sort. Visual observing outdoors in the dark usually means working to detect something extremely faint, tiny, hard to find, or all three. The more difficult the task, however, the greater the rewards of success. The joy of amateur astronomy lies in finding and seeing *with your own eyes* hidden marvels far beyond our tiny planet — things unsuspected by almost all the people over whose heads they pass — and in gaining skills and knowledge as an amateur scientist.

Too many beginners buy a telescope as if it were a TV set, expecting it to show them pictures all by itself. A better analogy would be with a home computer, which gives back only as much value as the work you put into it. Learning to use a telescope well isn't very hard, however. If you're reasonably persistent and careful and are willing to practice the techniques described here, you'll master the skies.

KNOW YOUR EQUIPMENT

Naturally, everyone first tries out a new telescope in the daytime. This is when to become familiar with its motions, pointing, focusing, different eyepieces, and magnifying powers, so you can then do everything in the dark.

Most telescopes have a finderscope attached to the side. You'll need to adjust the finder so it's aimed correctly. Using the lowest-power eyepiece, point the main telescope at some object a quarter mile or more away. Adjust the screws holding the finder until the object is centered in its crosshairs. Switch to the highest-power eyepiece in the main telescope and repeat the operation until the finder is locked in position with perfect aim. Even slight misalignment means much trouble later.

When looking through the telescope, focus and refocus with care. A good observer is always fiddling with the focus, trying to get it just a hair better. Many people find it best to keep both eyes open, since squinting strains the working eye. You can cover the "off" eye with one hand to avoid distraction. Use your other hand to shield extraneous light so that nothing gets into your eye but the image from the telescope. This isn't important in the daytime, but at night it can be crucial to seeing the faintest objects.

If you have an equatorial mount, set it up outdoors so the polar axis (the one with the setting circle showing right ascension) points about to where you know Polaris, the North Star, will be after dark. The motions of the mount now correspond to the paths of celestial bodies across the sky as the Earth turns. With the declination axis clamped, sweep the telescope in right ascension from the eastern horizon across the sky to the west to visualize star paths. At first the mount's motions will seem awkward and unpredictable. But remember that no matter where the telescope is pointed, it will move only in a line toward or away from Polaris (celestial north-south) and at right angles to this line (east-west). These directions vary in different parts of the sky (as shown in the illustration below), but with some practice swinging the telescope around you'll get used to them.

KNOW YOUR MAPS

By the time you own a telescope, you should have learned the constellations well enough to find your way around the sky. If not, get busy. A charming and very good guidebook is H. A. Rey's *The Stars*.

In addition to a constellation guide, you'll need a set of more detailed charts. You can always find the Moon, bright planets, and a few other prominent sights without good maps, but you won't be able to advance further. An amateur astronomer is only as good as his or her charts. So don't skimp here. Tirion's *Sky Atlas 2000.0* is the best all-purpose set currently available.

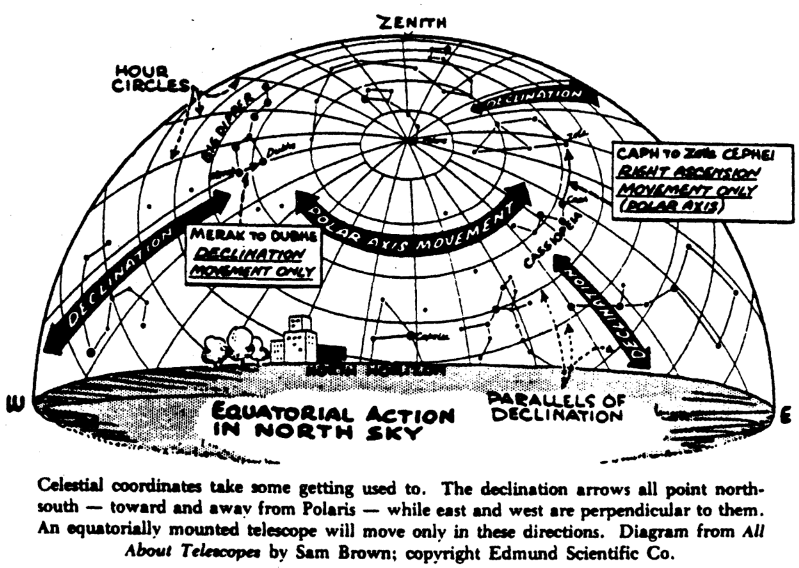
The charts may look terribly complex at first. But step back for a minute and look at only the brighter stars; they form the same familiar constellation patterns. Suppose, for instance, you've learned Gemini from the Rey book, where its stars are connected to form two stick figures holding hands. The same pattern appears in the lower left of Chart 5 of the Tirion atlas — but at a larger scale and almost hidden in a wealth of detail. Look up other constellations you know and examine how they appear on the charts.

East, you'll notice, is always *left* of north on sky maps, the opposite of land maps. The reason is simple enough: You look down at the ground but up at the sky. (If you looked up through the bottom of a land map of, say, the United States, it too would have its directions mirror-imaged.) When in doubt, remember that right ascension *increases to the east:* the hours of right ascension given on the map will always set you straight.

The next step is to learn the charts' scale. You have to know how much of your maps appear in the eyepiece before you can use them to find anything!

First determine the size of your finder's field. Locate two stars that just fit into its edges (try pairs in the Big Dipper) and see how many degrees apart they are on the chart, by referring to the declination scale along the sides.

Another way is to aim at a star near the celestial equator and time how long it



Celestial coordinates take some getting used to. The declination arrows all point north-south — toward and away from Polaris — while east and west are perpendicular to them. An equatorially mounted telescope will move only in these directions. Diagram from *All About Telescopes* by Sam Brown; copyright Edmund Scientific Co.

Sky and Telescope, Feb. 1984, pp. 131-133

takes to cross the field (with the telescope held stationary). The time in minutes divided by four gives the field diameter in degrees. Use this method to find the field diameter of the main telescope's lowest-power eyepiece. It will probably be only about 1° — the area your fingernail covers at arm's length!

Now, using the scale on the margin of the charts, make wire rings — or draw circles on clear plastic — corresponding to your field sizes. An example is shown in the photograph below. By sliding these devices across the charts, you can see exactly what star patterns pass through your field of view when you sweep across the sky. Beginners are always surprised at how tiny the fields really are. Keep these little tools with the charts; you'll need them whenever you observe.

We're now ready to go on our first deep-sky hunt.

STAR-HOPPING

Any observing session should begin with some indoor planning. Take out the charts and find an area of sky that will be well placed this evening. Let's use Gemini as an example. If you know the constellations, you can find its two bright stars, Castor and Pollux, in the sky. These will be our starting point. Castor itself is a famous double, consisting of two bright stars currently 2½ arc seconds apart, but let's try for more elusive game.

A couple inches southwest of Pollux on the Tirion chart is the planetary nebula NGC 2392, indicated by a little open circle with four spikes. According to ***Burnham's Celestial Handbook*** and other observing lists, it's a small, round glow of 8th magnitude; this is bright enough to show in most telescopes.

We'll plan how to get there by star-hopping. This just means following a trail of stars to move the telescope from a place we know, such as Pollux, to any spot we don't, such as the location of the nebula. The trick is not to get lost on the way. Follow each step on the picture at right.

Take the wire ring or plastic reticle that corresponds to your finder's field and center it on Pollux. Several fainter stars are in the circle, just as they would be if you were looking through the finder at the sky. The bright star closest to Pollux is 75 or σ Geminorum, to its north in the direction of Castor (which is out of the field of view). Near the southwest edge of the field is 69 or υ Geminorum. It forms a long right triangle with Pollux and 75, with Pollux at the right angle; this will serve to confirm its identity in the sky where there is no convenient label next to it.

Shift the reticle to center on 69; this corresponds to moving the telescope. Two new pairs of stars have entered the field to the west a little north of center: 64, 65, 60, and 59, forming a distinctive pattern. Shift the reticle to center on 60. The fainter 59 just to its southwest will confirm you've got the right one.

Star 57 is now just on the south edge of the field. Shift south by half the width of the field so 57 is centered; bright δ is now waiting just outside to the south. Shift south again an equal amount; δ quickly appears and can be centered just after 57 leaves to the north. See how δ forms an equilateral triangle with 56 and 63, to its south and east? With 63 identified — aided by the two fainter stars on either side of it — we're less than 1° from our prey. Note the flat triangle that 63 and 61 form with the nebula. The shape of this triangle allows us to move to the correct position even if the nebula is invisible, as it probably will be in the finder. The two faint stars just southeast of the nebula help confirm the exact spot.

FROM MAP TO SKY

If we do this outdoors at night and move the telescope to match each step on the map, NGC 2392 should now be visible in the main eyepiece: a small, dim, eerie round glow quite unlike the pointlike stars, grayish-green in color and with a very faint star at its exact center — a prize worthy of the rather complicated chase.

The star-hopping routine may seem like a lot of trouble to the beginner, whose impulse is just to sweep from Pollux "about the right distance *that* way." But most deep-sky objects are many times dimmer than the faintest stars on the chart and won't catch your attention even if, by luck, your tiny telescopic field happens to sweep over them. The only way to succeed is to know exactly where you are at all times. If you suspect you're lost, go back and start over. You'll speed up later when practice increases your skill.

The biggest pitfall in going from map to sky is keeping directions straight. Remember that north is not up but *toward Polaris*, no matter how cockeyed this direction may be. (It helps to turn your map accordingly.) In addition, your telescope and finder [redacted] give upside-down and backward images and may mirror-reverse* them as well. To correct for all these effects in your head, you'd have to be a genius. Instead, use a simple trick. While looking through the scope, nudge it slightly in the direction of Polaris; new stars will enter the *north edge* of the field, showing where this is. Nudge the scope east; stars enter the east edge. Now you've got your bearings. This trick will become such a habit that you'll forget you're doing it.

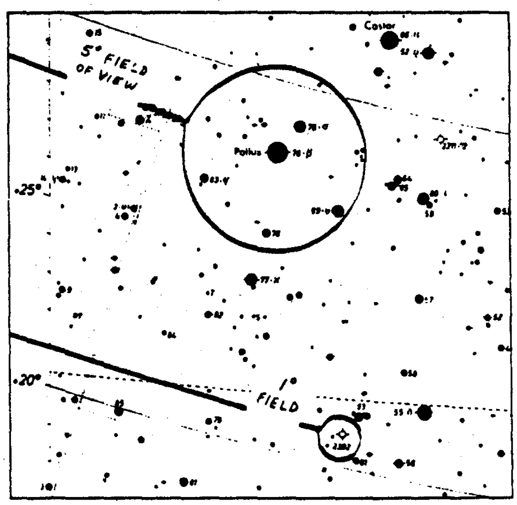
For this purpose, an equatorial mount is a great help. The polar (right ascension) axis must first be aligned on the north pole, however. For star-hopping this doesn't need to be done accurately. Just plunk the mount down so the axis is aimed at Polaris as well as you can judge. Better alignment methods, which are required for photography and accurate use of setting circles, will be described in another installment of this series. But even with rough alignment, the motions of the mount define north-south and east-west reasonably well.

Turn the eyepiece of the finder so the crosshairs line up with the telescope's motion as you sweep east to west. The crosshairs now show the four cardinal directions no matter where you point the scope.

When star-hopping, *always* think in terms of north, south, east, and west — never up, down, left, or right, or you'll quickly get lost in trackless wastes of space. Once you get the hang of it you'll always be mumbling as you turn from map to scope: "From the bright one in the north of the kite shape . . . half a finder field east to the pair in the triangle. . . ."

THE ART OF VISION

When you locate an astronomical object, don't expect to see right away everything it has to offer. The first look always shows



How much of a chart appears in your eyepiece? You'll be lost until you know. Handy aids like these tell at a glance. The large wire ring shows the 5° field of the finderscope on the author's 6-inch reflector. The small ring shows the 1° field of the telescope's 50-power eyepiece. Note the tiny size of the telescopic field, even on a large-scale chart like Wil Tirion's *Sky Atlas 2000.0*. Examining the sky at 50 power is like examining the chart with a microscope.

* If you use the diagonal mirror, your main scope image will be left/right reversed but no longer upside down.

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less than comes out with continued scrutiny. This is true whether your subject is a dim galaxy that can hardly be told from the blackness of space, or detail on the Moon or a planet where the light is almost blindingly bright.

One reason it takes time to see detail is the unsteadiness of the Earth's atmosphere. Celestial objects constantly shimmer and boil when viewed at high power. The severity of this shimmering — called the *seeing* — varies from night to night and sometimes from minute to minute. As you watch an object quiver and churn, unsuspected detail will flicker into view during quick moments of stability, only to fade out for a while before being glimpsed again. The skilled observer learns to remember these good moments and ignore the rest. The seeing quality is most evident with bright objects, but it can influence the visibility of faint ones too.

The main reason it takes time to see detail, however, has to do not with the atmosphere but with the eye and mind. In daily life we're used to seeing things easily. If something can't quite be made out, our reaction is to move closer for a better look. But in astronomy this is impossible. Instead, we have to wring everything we can out of very distant views. This means learning new visual skills that involve active, concentrated effort.

You'll discover that the eye's picture of a difficult object builds up rather slowly. First one detail is noticed and fixed, and you think there's nothing more to be seen. But after a few minutes another detail becomes evident, then another. To convince yourself of this, look at a piece of sky and try to spot faint stars. Some will be visible right away; others take a few seconds to come out. When no more appear, most people would quit trying. But keep at it for a few minutes. Chances are quite a few more will glimmer into view, in places you would have sworn were blank. After a while you're seeing at least half a magnitude fainter than at first.

The planet Mars is another classic example of this effect. For the beginner taking a first look with a small telescope, it ranks as the most disappointing object in the sky. It's just a tiny, featureless, orange fuzzball. The beginner steps aside to let an experienced Mars observer at the eyepiece. Silence. "There's the north polar cap. . . . That big dark area in the south must be Mare Erythraeum. Okay, I've got Sinus Meridiani. . . . There's a cloud patch on the western limb. . . ." The beginner looks again. Nothing but a fuzzball. Well, maybe there *is* a bit of brightness at the north edge crawling around in the poor seeing, and the fuzziness isn't a *perfectly* uniform orange, but these hardly seem like things that are worth noticing. Nevertheless, the next time the beginner looks he or she won't be quite a beginner, and that bright spot and

The Greek Alphabet

The brighter stars of each constellation have been identified by lowercase Greek letters ever since Johann Bayer, a German lawyer, introduced this system in his star atlas of 1603. Everyone who uses star charts should memorize the Greek alphabet:

α Alpha	ι Iota	ρ Rho
β Beta	κ Kappa	σ Sigma
γ Gamma	λ Lambda	τ Tau
δ Delta	μ Mu	υ Upsilon
ε Epsilon	ν Nu	φ Phi
ζ Zeta	ξ Xi	χ Chi
η Eta	ο Omicron	ψ Psi
θ Theta	π Pi	ω Omega

dark area will come to view more readily.

"You must not expect to *see at sight*," wrote William Herschel, often considered the founder of modern astronomy. "Seeing is in some respects an art which must be learned. Many a night have I been practicing to see, and it would be strange if one did not acquire a certain dexterity by such constant practice."

An excellent way to train yourself to see better is to make sketches. These don't have to be works of art; the idea is just to record details more conveniently than in words. Star fields require no artistic talent whatsoever, but by sketching a field that contains a faint asteroid or outer planet, you can identify the object in the next few days or weeks as it changes position.

For practice sketching planets, start on the Moon with the naked eye; it shows more detail this way than any planet will in the telescope. Make a semicircle a couple of inches in diameter by tracing some round object and then draw in the terminator exactly as you see it in the sky. Carefully add the major dark areas with pencil shading, then look for finer markings. By now (assuming you have normal or properly corrected vision) you'll be seeing much more detail on the Moon's face than you ever thought possible without optical aid.

"The lesson is clear," writes James Muirden in *The Amateur Astronomer's Handbook*:

> No opportunity should be lost to train the eye to work with the telescope; to observe the same object with different powers so as to see the effect of magnification; to try to see faint stars; and to draw planetary markings. In the beginning, to be sure, this may all seem to be wasted effort; the observing book will fill up with valueless sketches and brief notes of failure. But this apparently empty labor is absolutely essential; for, as the weeks pass, a steady change will be taking place. Objects considered difficult or impossible to see will now be discerned at first glance, and fainter specters will have taken their place. Indeed, these former features will now be so glaringly obvious that the observer may suppose that some radical improvement has occurred in the observing conditions. But the credit belongs entirely to the eye. . . .

LIFE'S LITTLE COMFORTS

Naturally, this sort of concentration will be spoiled by any undue discomfort or inconvenience at the telescope. You'll need a table right at hand to hold charts, red flashlight, eyepieces, notebook, pencil, and other oddments. A wonderful solution for me has been a cheap card table with fold-up legs. It's big, very light, and easy to carry and store. And it cost only $4 in a secondhand shop.

Nothing ruins your ability to see like having to twist and strain to look through the eyepiece. A rotating tube is therefore a great plus in a small reflector and almost mandatory in a large equatorially mounted one. If you can find (or make) an adjustable-height observing chair, your telescope may start showing whole new worlds. I've made do with an assortment of seats from a milk crate to a baby's high chair; pillows provide "fine adjustment."

Any jerkiness and backlash in the mount's motions can also spell doom, especially if you lack a clock drive. Make sure the telescope is balanced properly by adjusting any counterweights. Don't be afraid to take a mount apart and lubricate it, or to return it to the dealer if it's unsatisfactory. The mount I bought for my 6-inch Newtonian years ago was originally quite jerky. After trying every lubricant, I found that the best was candle wax rubbed on all the bearing surfaces. The "clamps" in both motions were merely bolts that tightened head-on against the shafts; I epoxied small pieces of leather to the bolt ends, impregnated these with graphite and a little oil, and thus gained adjustable tension. The improvement was enormous. At high power I could follow the stars with a smooth, continuous motion just by pressing the side of my nose lightly against the eyepiece.

Almost any telescope will wiggle a little when you touch it. In an ideal world this might be cause for sending it back to the manufacturer. But unless you are willing to pay for, or build, an observatory-class mounting, you'll have to live with it. If the wiggling keeps you from finding the sharpest focus at high power, however, or if it doesn't cease when you let go, you do need a better mount. As you become more adept at handling your scope, you may get used to wiggles that at first seemed a bit disconcerting.

In wintertime, you can either heed the astronomer's standard advice to dress for at least 20° F colder than the actual temperature, or you can learn this the hard way.* As for the summer, it remains a mystery how successful observations were performed before the invention of mosquito repellent.

In short: Anything that makes your observing easier, surer, or more relaxed, no matter how much trouble it takes beforehand, is well worth the effort.

* For reasons which are not at all clear to me, many 12s23 students learn this "the hard way."