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

## "Chez 12.409" Menu for Spring 2002

This handout is intended to give you some direction as to what you might want to hunt for with your telescope. It's divided into sections as follows:

# Contents

## *Reference information*

Celestial coordinates for the clusters, nebulae, variable stars, and galaxies included in this handout are provided in the table on page 12.

<u>More Information</u>: This handout is intended to help you select what to observe. In order to actually locate the objects in the sky, you'll need some additional "at-the-telescope" reference material:

- *The Stars* by H. A. Rey. Superior naked-eye introduction to the constellations, including much of the lore going along with them. (Lindgren Library course reserve) 12.409 has copies you'll use while observing in class.

- *Sky Atlas 2000.0* - a rather large ringbound set of star charts showing stars to 8th mag. It's well-suited for locating objects with our LX200's and is in year 2000 coordinates. (Lindgren Library course reserve; Science Library map room) 12.409 has laminated copies you'll use outdoors while observing in class, as well as regular paper copies for use indoors.

- *Norton's 2000* -useful for finding brighter objects (down to mag. ~ 6) or for use with binoculars.  This 18th edition is fairly recent; you may see the 17th edition (*Norton's Star Atlas*) around as well.  The main difference is that the new version is in 2000 coordinates while the older is in 1950. (Science Library Map Room; CSR Reading Room)

Additional reference materials, more appropriate for ``desk work'' such as making finder charts, computing observability, or obtaining detailed information about objects you're observing, include:

- *The Astronomical Almanac 2002* - the "official" reference for more careful work, with LOTS of information (some of which is even useful for 12.409 work), including rise and set times for the Sun and Moon, coordinates for planets, bright asteroids, stars brighter than 5th magnitude, (Lindgren Library; Science Library map room ; CSR Reading Room; 12.409 classrooom).

- *Uranometria 2000.0*, *Vols. 1 & 2* - hardcover atlas with stars to mag. 9.5.  Ideal for photocopying to make finder charts for harder objects!  (Lindgren Library ; Science Library map room; 12.409 classroom).

- *Voyager III* application for Macintosh (installed on ibook computers in 12.409 classroom)

- *HST Guide Star Catalog CD-ROMs* and *Pickles* application for Macintosh -most useful for making charts to use when tracking down faint objects with our CCD cameras (Lindgren Library; 12.409 classroom)

- *Burnham's Celestial Handbook, Vols. 1--3* - The "ultimate" source of detailed information about objects you're observing. (Science Library, CSR Reading Room; 12.409 classroom).

Finally, note that the contents of this handout are intentionally restricted in scope to primarily those objects visible in the *evenings* during the Spring.  More general information about what interesting celestial targets are up when can be found in:

- *Astronomy* magazine (monthly).  The section titled "Sky Almanac" has a few subsections: "Eye on the Sky" dealing with naked-eye observations, "Through the Eyepiece" dealing with telescopic targets, and a useful chart of planetary data. (CSR Reading Room) (stocked by "Out Of Town News" in Harvard Square)

- *Sky and Telescope* magazine (monthly), with columns "Rambling Through the Skies", "Celestial Calendar'", "The Evening Sky", and "Stars & Planets". (CSR Reading Room) (stocked by ``Out Of Town News'' in Harvard Square, also see  www.skypub.com)

# 1 Without the Telescope

Whenever you can, try to get in some naked-eye observing on clear nights outside of class time.(Also try binoculars, if you have them.) It's not bad as a study break---grab a comfy chair, a copy of Rey's book and some cookies (and maybe a sweater), amble on up to the roof of your living group (maybe not if it's MacGregor, though)  and just mellow out under the sky.  *But*, you say, *what will I be able to look at on clear nights which* **aren't** *my lab night ,when I* **won't** *have a telescope?*

Well,

- Do you know how to tell the compass directions at night? (If you don't already, you will REAL SOON; you'll need to get through one of the checkpoints in the class.) Start by finding North to get your bearings.

■   Can you identify these constellations?

Andromeda
Cepheus
Lyra
Perseus
Bootes
Cygnus
Orion
Taurus
Cassiopeia
Hercules
Pegasus
Ursa Minor

(Fainter constellations such as Cancer or Monoceros are difficult to see in Cambridge, since only the brightest stars show up here.  MUCH less of a problem at Wallace Observatory!) You do need to learn the brightest stars and constellations in order to be able to find your way around the sky with binoculars, or with small telescopes such as ours. If you don't yet know those 12 listed above, this is where having a copy of Rey's book with you really can help out.

■   Where is the Moon in the sky? (Also try to find it during the day if it's visible.)    When and where did/will it rise? Set?  What phase is it in now?  Is is waxing (getting bigger) or waning (getting smaller)? Where is it with respect to the stars?  The position of the Moon changes SIGNIFICANTLY, about $12^{\circ}$ to $15^{\circ}$ from night to night.

■   *Predict the next full moon* - Plot the Moon's positions  through the stars for a few weeks, carefully sketching the phase at each observation. Make a diagram of the Earth and Moon's orbit, showing the direction in which the Sun lies.  Label the appropriate position on the orbit with the corresponding date of each of your observations.  With enough observations, you should be able to calculate a date for the next full moon - check the *AA* afterward to see how close you came!

■   *Plot a Planet's Path* – Jupiter and Saturn are up all semester. They are easy objects to find, so it's easy to record their motion on a star chart.  Photocopy the proper pages out of (in Uranometria 2000) and affix them to pages in your notebook.  Each observing night, look at one (or both) using your finderscope---although the planets are bright enough to see without optical aid, the field stars near Jupiter and Saturn might not be easily visible from Cambridge without using the finder.  Plot the positions as accurately and as precisely as you can, recording the date and time of each marked position.  In which direction is each moving, and how fast?  Do they appear to change direction over the course of the month?  Do you have enough positions to tell if/how the apparent *speed* of motion changes over the course of the term?

■   Can you find the constellation corresponding to your so-called astrological "sun sign"?  Is it even up for viewing anytime this term? You can use the Sun's coordinates in *Astronomical Almanac* together with a *Sky Atlas 2000* or *Uranometria 2000* to figure out which of the **thirteen** constellations which lie along the ecliptic the Sun is **really** in on your birthdate---it **won't** be your so-called "sun-sign".  (We will get to seeing why this is the case.)

When you go out for an eyes-only session, feel invited (coerced, exhorted, cajoled) to bring along your Observing Notebook, and FEED IT!

# 2 (❍ easy) Moon; Bright Planets & Deep Sky Objects

## *2.1 The Moon*

The Moon isn't up during the first week of the class, but is around for the end of it. It's a bit of a shame since it's a great object for beginning observers. Nevertheless, we can enjoy it when it shows up. Sketch the phase of the Moon (e.g. "full", "waxing crescent"), then try your hand at drawing in some of the larger surface features. (If it's uncomfortably bright through the LX200, use the Moon filter.) How much of the Moon can you see at once through the finder and through the various eyepieces? Try different eyepieces to obtain the magnification that gives the best views for the prevailing sky conditions. What, in your opinion, did this optimal magnification turn out to be? (A more complete observing guide to the Moon is included in Section 3.1 as "intermediate"-level observing.)

## *2.2 Planets*

1. **Jupiter** – The "King of the Planets" rules the skies all month long. Jupiter is at opposition this month, and is also unusually close to Earth Shining about mag. -2.6. Jupiter is a large bright feature-filled object. At low power, you see a small oval disc flanked by some or all of its four bright Galilean moons. Even with low powers you'll be able to pick out one or two of the dark cloud (belts) near its equator. Higher powers will reveal smaller features *only* if the seeing is good (if the stars are twinkling madly forget it - you won't be able to use your telescope's resolving power to its fullest). If we **do** get a good night, you should be able to observe the Red Spot if it's facing us, on the south edge of the south equatorial belt. Careful observations of these details can show visible changes even over the time span of only one night's observing, since Jupiter rotates once on its axis every 10 hours, and the inner satellites move fairly quickly in their orbits around Jupiter. A blue eyepiece filter helps to increase contrast of the dark band(s) and Red Spot (also try yellow-green, green, and orange).

   Try to observe Jupiter each opportunity you get! Take care to accurately record the positions of the visible Galilean satellites, so that it will be possible to properly identify each with its name. Avoid just taking a hurried look and then moving on to something else - take some time and give your eye a chance to really *see* what's there, particularly if our sky conditions are favorable. (Jupiter's almost always worth at least 10 min. of observation, minimum.) In order to observe more belts and hints of spots, patches, and other detail, you'll need to keep watching for many minutes to catch the moments of good seeing and study the disk carefully.

2. **Saturn** - Available all semester (but in the later part only early in the evening). Saturn's bright at around mag. +0.7 this term, sitting in Taurus. This term its rings are wide open, near their maximum, so the shape of an object you think is Saturn should be unmistakably elliptical even at low power. If conditions are good try viewing Saturn through your yellow filter; it may help reveal some non-uniformity on the disc you see (also try other colors, and record your "results"). Locating and positively identifying brightest satellites Titan (mag. +8.3) and Rhea (mag. +9.7) is an only slightly more difficult project: you need to compute their expected locations, most easily done using the *Voyager III* application, or online sites (see your instructor for details).

3. **Mars** - Spring 2002 we find Mars hanging very low in the southwestern sky for the first half of the term. It fades from mag. +1.0, as Earth pulls steadily away over the course of the semester and its size decreases steadily. How big is it at the start of the class relative to the end? Mars will be a tough observation to make relative to Jupiter and Saturn.

4. **Other Planets** – Unfortunately, the other major planets (Mercury, Venus, Uranus, Neptune, and Pluto) are all poorly situated for observing this Spring. They're all too close to the Sun to see. That's OK, we don't need them anyhow.

## *2.3 Some Stars*

Starting with some objects that *should* make easy finding…

1. Use a star atlas to locate these stars by greek letter in the indicated constellation, then find them visually with your telescope.

   a. α Canis Majoris (Sirius, in Canis Major) - What color does this star appear to be?  Sirius is the brightest star in our sky at mag. -1.4.  Low in the eastern sky during class time.  Try the following while it's still in the murk below 20°:

   - Compare the unfiltered image of Sirius with that of Capella (a star nearer the zenith:  **Zenith** is the point in the sky directly overhead) at the same high magnification.  Can you detect any difference in overall quality, and in size?  Why would there be a difference?

   - Compare the size of Sirius' image at high magnification (use your 12mm eyepiece with the 2x Barlow lens to get 340x  as seen through blue and through orange eyepiece filters. Can you detect any difference in size?  Why would there be a difference?

   b.  α Aurigae (Capella, in Auriga) -  what color does this star appear to be?

   c. β Ori (Rigel n Orion) - What color does this star appear to be?

2. Sketch the fields of these *double stars*.  Locate each using your lowest power (i.e., 6x), using your finder scope) and then work up in magnification until you can resolve the pair.  Given the field of view sizes for the eyepieces in which they can be resolved, estimate the angular separation between the component stars.

   a. ι Cancri (in Cancer) - sketch the star field.  How do the two component stars differ?  Try viewing this pair slightly out-of-focus to intensify color.

   b.  β Monocerotis (in Monoceros) - Carefully sketch the star field; you'll need to use fairly high magnification for β Mon to appear double.  In what ways do β Mon and ι Cnc differ?  If the sky conditions are particularly good, try to inspect the component stars very carefully at your highest power.  Notice anything?

## *2.4 Clusters and Nebulae*  Locate, describe and sketch each of the following objects (For coordinates of objects here, see the table last page of this handout:

1.  M42 in Orion - The "Great Orion Nebula": a bright diffuse *emission nebula*, about 1300 light-years away.  You should be able to locate this one VISUALLY in order to point the telescope, even in Cambridge, but in case you wimp out, its coordinates are in the table at the end of the handout. M42 contains stars in  formation; look for the "Trapezium", a knot of four stars near the middle.  These four young hot stars apparently supply most of the energy which excites the nebula's hydrogen gas, making it glow.

2.  M45 in Taurus – "The Pleiades": an *open cluster*.  This is another object you should have little trouble finding without the telescope in Cambridge.  A large object - sketch the view *through the finder scope* (6x  since the whole cluster won't fit in the field at the higher magnifications using the LX200).  Its worthwhile to try drawing a smaller area in more detail using lowest power eyepiece as well.  Do you know what car company takes its name from this astronomical object?

3.  M44 in Cancer - The "Beehive Cluster": another open cluster.  Barely visible to naked eye under *good* conditions as a faint glow or hazy patch of light.  It's a sprawling cluster, so you must use the low power eyepiece to be able to get a reasonable amount of it in the field. Look for the ``beehive'' itself: the trapezoid formed by mag. 6.5 stars at the heart of the cluster.

4.  h and X Persei in Perseus (also called NGC 869 and 884) - The "Double Cluster": a pair of open clusters.  A large object - sketch it in your finder scope and lowest power (pair just *barely* fits in field at 50x).

5.  M3 in Canes Venatici - a ***globular cluster:*** a few tens or hundreds of thousands of stars in an essentially spherical dense concentration. Being near Arcturus, M3 rises a little late for us early in the term, but becomes more cooperative after a few weeks.

6.  M13 in Hercules - The "Hercules Cluster": one of the most famous globular clusters. Contains about 300,000 stars, 24,000 light-years away.  Only available the last month of the semester.

**2.5 Galaxies**  In general, galaxies are NOT easy objects; M31 is the only exception.

1.  M31 in Andromeda - the "Andromeda Galaxy": a ***spiral galaxy***, similar to our own and (relatively speaking) close by; it's only 2,400,000 light-years away.  It is only available during the first half of the Spring term.  We see it tilted about 15$^o$ from edge-on.  Can you see it in Cambridge without the telescope? (At Wallace observatory, you would be able to find it visually, without the telescope.)  Use your lowest power to find it.  Sketch its appearance through the finder scope and through the available eyepieces.  The nucleus is easy to see; the fuzz of the spiral structure is much more difficult: estimate its angular size through the LX200, and compare this with the extent of its ellipse as plotted in the *Sky Atlas 2000*.

# 3 (☐ intermediate) Lunar Features and Non-trivial Deep Sky Objects

This set of objects is designed to refine and sharpen your observational skills. You will be trying to find some more difficult objects here; be patient and thorough.

## 3.1 The Moon Again

The Moon is one of the most rewarding celestial objects for viewing with a small telescope.  Since it is so nearby, the Moon shows far more detail than anything else in the sky, even without using any telescope. (Besides, there's no problem finding it).  The idea here is to become familiar with the various types of features visible on the lunar surface.

Which particular types of features are best-viewed on a given night depend somewhat on the lunar phase.  The best time to view craters and mountains is when they lie along the *terminator*, which divides day and night on the Moon. There, the sunlight strikes features at a glancing angle causing them to cast long shadows which helps a great deal to bring out topographic (strictly speaking, "selenographic") relief visually.  The terminator is particularly rich in relief near First Quarter (and Last Quarter) phase. In contrast, the flat light and dark areas and the lunar rays will be more clearly seen *away* from this shadow line, especially around Full Moon phase.

*n.b.* It may be wise to consider using the eyepiece-mountable ``Moon filter'' in your kit if you plan to be observing a substantially-lit Moon for a fairly long time; it's a very bright object! (up to mag. –13!).  (The kit has an assortment of colored filters too, if you're feeling particularly artistic).

**Begin** by making a LARGE rough sketch of the visible lunar surface, mainly to serve as a sort of  "scaffolding" within which you can subsequently make your more detailed observations. ***Don't*** *spend too much time on this first sketch!* Include only large dark patches, very noticeable craters, and other large features.  Once you've got your large sketch, you can proceed with some more detailed observations by selecting and answering questions from the following list, adding features to your sketch and indexing them appropriately as you go along.

One way to handle this is to use the "question number" from the list as a short label for the feature on the sketch itself, (*e.g.*, labeling a feature 2e on the sketch itself and noting 2e = crater with center peak) in your notebook. As you sketch and index the features in your notebook, leave space for the correct given name of each.  Back inside, you can use a printed *Sky and Telescope Lunar Map* to find the correct name for each feature you observed. If you want more

detailed reference maps, go to the Stein Map Room in the Science Library or to the Lindgren Library (54-200) and use a lunar atlas there.

If you look for but can't find an example of a particular feature, then record *that* fact in your notebook. Of course, feel free to sketch in any other features or structure you find intriguing.

1 The lunar "seas":  **maria**, the flat darker gray lunar plains
a)    Estimate the percentage of visible surface covered by maria.
b)    What is the general shape of the maria?
c)    In general, are the maria connected to one another? Try to find an example of a lunar plain which is *not* connected to the others.
d)    Can you find areas which differ distinctly in reflectivity (darker or brighter) from that of the rest of the surface?
e)    Some of the mare floors show wavelike ripples when sunlight strikes them at a glancing angle (*i.e.* near the terminator).  Try to find an example of this effect.
f)    Can you find examples of different sorts of interaction between craters and maria?  Which appears to have happened earlier in lunar history:
    ▪    larger-scale cratering, or
    ▪    formation of maria?

g)     Examine the ``Straight Wall'' cliff, in eastern Mare Nubium. (labeled xx on the Lunar Map, near crater Birt {#37) It's 130 km long, 180 m high, slope of 40°).

2.  The lunar **craters**
a)     In which quadrant of the visible surface do most of the craters lie?
b)     In general, which wall of a crater (inner or outer) is steeper?
c)     Do most of the crater floors appear to be above, below, or level with the general ground-level of the surrounding region?  Try to find at least 1 example of each of these 3 cases.
d)     The largest craters, such as Clavius, Plato, and Ptolemaeus, are often called *walled plains*.  Find one and contrast its shape and outside wall or lack thereof with that of the more moderately-sized craters.
e)     Do all large craters have central peaks?
f)     Are peaks always at the center?
g)     Can you find an example where the central peak exhibits a hole at the summit?
h)     Can you see examples of small craters on the rims of larger craters, deforming their walls?
i)     Locate and examine a few twin craters.

3.  The lunar **mountains** - you can use the *Lunar Map* to easily locate one or more visible mountain ranges.
a)    Do the mountain ranges appear in general to be straight or curved?
b)    Does one side appear to be steeper, in general?
c)    Look for a mountain peak (or a high crater wall) on the night side of the Moon, *just* over the terminator, that rises high enough to catch some of the rays of the rising Sun and shine like a bright spot of light.

4.  Lunar  **rays** - these are best seen with Sun "overhead" (shadows absent).  Craters Tycho and Copernicus have particularly notable ray systems.
a)    Are the rays continuous across the lunar surface?  Do rays appear to pass equally well over maria, crater walls, and mountains?
b)    Do rays always appear to radiate from crater centers?
c)    Estimate the lengths of the rays associated with one crater (your choice!).  (The diameter of the Moon is about 3480km.)

5.  **Rilles** and **craterlet chains** - *Rilles* are long narrow cracks in the surface, half a mile or so across.
a)    Find some rilles.
b)    Can you tell if rilles appear to be associated primarily with one specific type of lunar feature or are they fairly uniform in distribution?

c)  Note that at high powers under conditions of good seeing, some rilles will be revealed to really be *craterlet chains* (e.g. the Rheita Valley, labeled S on the Lunar Map, near crater Rheita #251).  Locate and examine one or more chains of craters.

d)  Examine the `"Alpine Valley"', a deep straight gorge cutting through the lunar Alps at the northeast corner of Mare Imbrium. (labeled aa on the Lunar Map, near crater Protagoras #238)


## 3.2 Variable Stars - making visual estimates

The stars listed here vary in brightness fairly regularly over a period of a few days.  *If you observe one or more of these stars carefully on two or more different nights, you should be able to detect these changes.*

To make a visual estimation of the magnitude of a star, sketch the field you'll use (including the variable). Choose a number of other stars in the field and assign them each a letter name in order of decreasing magnitude (e.g., A = brightest, B = not quite as bright as A, ...), recording the letter names on your sketch.  Then make an estimate for the variable star, so that on a scale of 1 to 10 between two ``lettered'' stars, say B and C, a B2 would represent a brightness about 20\% of the way from B down to C (brighter than C by about four times as much as it is fainter than B).  Keep your eyes moving; look back and forth repeatedly among the 3 stars (brighter, fainter, variable) and judge the variable's brightness as best you can.  (Don't worry about trying to assign numerical values for the magnitudes at the telescope.)

It is important that you approach the brightness estimation task without letting any preconceptions of "what you think the star *should* be doing" affect your work.  At first you may find it difficult to distinguish between brightnesses which are less than 0.3 or 0.4 mag. apart; brightness estimation skill is improved only by practice.


1.  β Persei (Algol, in Perseus) - an *eclipsing binary* - orbiting pair of stars of different brightnesses whose orientation causes them to eclipse each other as seen from Earth.  A bright (bright enough for Cambridge!) variable star with a short period.  [$\Delta m = 1.3$; period = 2.9 days]  Using Rey's book or the atlas, you'll be able to locate it with your unaided eye, and will need to estimate its brightness relative to other nearby naked-eye stars (i.e. don't use the telescope at all for this one; even the finder field is too small a field).

***Suggestions for estimations using the LX200***:

- This type of work is best done with a low-power eyepiece. If the variable is the brightest object in the field, try using the finder scope; you want at least one star in the field to be brighter than the variable so you can make an accurate estimate.  It isn't as instructive to know only that the star was brighter than 7th magnitude if the star was actually varying between 7th and 5th magnitude.
- Center the star(s) in your field of view (to avoid vignetting, false contrast with inside of tube).
- Try viewing the star(s) slightly out-of-focus: apparently it's easier to compare the brightnesses of discs than of pinpoints.

2.  HU Tauri (in Taurus) - another eclipsing binary. [$\Delta m = 0.8$; period = 2.1 days] Although plotted in the *Sky Atlas 2000}*, the *12s23 Atlas Supplement* (hanging around the room) goes one better, with a copy of *Uranometria* chart #134 for use as a finder chart.  You'll probably need to use your finder scope to get a good set of in-field comparison stars.  HU~Tau has a fairly small magnitude range, so make your estimates as carefully and as accurately as you can.


## 3.3 More Clusters, Nebulae, Galaxies

For these objects, the task of finding them at all among trackless expanses of stars is non-trivial, mainly because it's not nearly as obvious when you've successfully got one in your field.  To locate them, you'll need to be fairly adept at using star charts and finding your way around confusing star fields. (Any awkwardness with charts in the dark spells trouble.)  Your success or lack thereof also depends on your eyesight and the prevailing sky conditions, so please keep

that in mind as you begin to consider throwing your partner off the roof out of sheer frustration. (We note, in fairness, that you have a couple of "secret weapons" we'll let you in on partway through the semester…)

When you do find one, draw what you see, with different eyepieces if there is a distinction. Normally you'll want to stick with low power to get brighter images. Note especially the important characteristics, such as angular size, shape, and any visible color. Using "averted vision" may help you see faint objects. You can also try using the ``LPR'' (Light Pollution Reduction) filter to increase contrast by darkening the sky background (works best on emission nebulae).

1.  **Rosette Nebula** (NGC-2237, -2238, -2239, -2246; and open cluster NGC-2244) in Monoceros - a diffuse emission nebula. You won't see this one visually: even though it's about three times the size of the full moon, it is an EXTREMELY LOW-CONTRAST nebula. It's included here as an intermediate-level target for CCD observations (from Wallace?) rather than for sketching. To observe it, use the LX200 to locate NGC-2244, the open cluster it lives with.

2.   M1 in Taurus - The **Crab Nebula**, a diffuse emission nebula. Remnant of the Supernova of A.D.1054. Be patient! A small AND faint object!

3.  M38 in Auriga - an open cluster

4.  M81 in Ursa Major - a spiral galaxy seen face-on

5.  Bubble Nebula in Casseopia (aka NGC 7635) – Bright Nebula (HII region)

6.  M5 in Serpens – Globular cluster available late in the semester

7.  M92 in Hercules – Globular cluster also available late in the semester.

8.  M64 in Coma Berenices – The **Black-eye Galaxy**, a spiral

9.  M104 in Virgo – The **Sombrero Galaxy**, a spiral seen almost edge-on. A small object that would fit nicely in the CCD FOV.

10. M57 in Lyra – The **Ring Nebula**, a planetary nebula. A small object that looks somewhat like a "focus doughnut."

**3.5 Alien Spacecraft** Note especially any bumper stickers on the spaceship (as information about alien society).

➡ Above all, it's important to **FEED YOUR NOTEBOOK**!

# 4 (♦ expert)  Faint Planets, Asteroids, and Other Challenging Stuff

## 4.1 More Planets

As mentioned, earlier, Uranus, Neptune, and Pluto, which would normally go in this section, are not even theoretically possible during Spring in 2002.

## 4.2 Asteroids

Typically at least one or two of the four largest asteroids will be bright enough to observe using our telescopes. Locating and positively identifying an asteroid takes a bit of extra effort since they move significantly each day, so you need an accurate finder chart that also shows stars at least as faint as you expect the asteroid to be. To observe an asteroid, star-hop to its location as shown on your finder chart, and then at low magnification *carefully and completely* sketch the pattern of field stars you see. Hopefully one of those "stars" is really your asteroid! Be sure to save your

finding chart, so that the next night you observe you can verify that the asteroid really *was* in your field by finding and sketching the same field a second time; your asteroid will be the object that moved!

**Making a finder chart:** The charts can be made using the *Voyager III* application. This is an especially straightforward approach because the software handles both calculating the asteroid position as well as plotting it on a star chart.

But you can plot a finder chart even if you don't have a spiffy program to do it for you, as long as you can get hold of an ephemeris (**Ephemeris** is astronomer-speak for a tabulation of an object's RA, Dec, and distance for some set of times at regular intervals. Complete ephemerides (plural form) for the four brightest asteroids 1-Ceres, 2-Pallas, 3-Juno, and 4-Vesta are printed each year in the *Astronomical Almanac*; partial tables for other asteroids which are fainter but still potentially observable with small telescopes appear from time to time in *Sky and Telescope* and *Astronomy*, usually with finder charts. Various online sources for asteroid ephemerides also exist—ask Andy for their addresses) for the asteroid covering the time you wish to observe. You'll need a star atlas that shows stars at least as faint as the asteroid, such as *Sky Atlas 2000* (to mag. +8), *Uranometria 2000* (to mag. +9), or the brand new *Millennium Star Atlas* (to mag. +11). (Remember that you need to use a chart referenced to the same equinox as the coordinates you have, usually 2000. Watch out for older charts in 1950 coordinates!) Photocopy the appropriate chart and plot the asteroid's position at five- to ten-day intervals lightly in pencil, then draw a smooth curve passing through all the points.

Another way to handle the observations is reminiscent of the way asteroids are discovered today—when we begin using CCDs on the telescopes, move the telescope to the field containing the asteroid of interest (several relatively bright ones available this semester are listed below), and take several integrations separated by a few minutes. You should easily be able to see the asteroid move relative to the background stars. If the exposure is long enough and the asteroid is moving fast enough, you might even be able to get the target to leave a trail (this exercise is left for the reader…).

**Plausibly observable asteroids this semester:** Vesta (pieces of Vesta have fallen to Earth), Mathilde (faint, maybe too faint. The first body visited by the NEAR Shoemaker spacecraft), Juno, Zelinda, Kalliope, Papagena, Flora…

## *4.3 Still More Clusters, Nebulae, Galaxies*

1.   open cluster M103 in Cassiopeia (quite a small one)

2.   "Owl Nebula" - planetary nebula M97 in Ursa Major

3.   irregular galaxy M82 in Ursa Major, seen on-edge

4.   Globular cluster NGC 2419 (quite faint and small), possibly not gravitationally bound to Milky Way

5.   spiral galaxy M66 in Leo

6.   spiral galaxy M65 in Leo

7.   "Whirlpool Galaxy" - spiral galaxy M51 in Canes Venatici, seen face-on. Fairly close to the zenith late in the semester; so do some neck-stretches to loosen up beforehand.

8.   irregular galaxy M82 in Ursa Major, seen on-edge

9.   globular cluster M107 in Ophiuchus available late in the semester.

### *4.4 More Variable Stars*

1.  VZ Cancri: (a pulsating variable) - one kind of star that intrinsically changes in brightness.  [$\Delta m = 0.7$; period = 4.3 hours]  This star's brightness sports a rapid rise followed by a slower fall.  Its period is short enough that you should be able to detect a brightness change over the course of only one night's observing, if you make your brightness estimates carefully.  Use your finder scope field and compare the star with field stars to its N and NW. Try making observations at intervals of about 1 hour, at the beginning, middle, and end of class.

2.  ζ Geminorum (in Gemini): one of the brightest ***Cepheid variables***, another type of intrinsic variable. [$\Delta m = 0.5$; period = 10.2 days]  You should be able to find it `eyes-only' by using the *Sky Atlas 2000*.  ζ Gem has an abnormally symmetric light curve but a fairly small magnitude range, so make your estimates as carefully and as accurately as you can.  This is a candidate for naked-eye comparison (no telescope); The two nearby stars κ Gem [mag. +3.6] and υ Gem} [mag. +4.1] correspond closely in brightness to the extrema of ζ Gem.

3.  U Geminorum:  Namesake of the small class of stars "U Gem/SS Cyg type, with outbursts'", sometimes called ***cataclysmic variables*** or ***mini-novae***.  [$\Delta m = 6.7$; unpredictable period ~ 60 to 260 days] Use your 40mm eyepiece to get 50x.  This will probably be one of the most challenging objects to find --- don't become discouraged if it takes some time (like attempts on more than one class night), because it glows faintly at only mag. +14.9 during the fainter part of its cycle.  14.9 is really pushing beyond the visual limits of an 8-inch telescope, even under ideal conditions, so don't feel incompetent if you decide it's invisible (even from Wallace).  But most importantly, you should learn the star field, because that way, you can set an upper limiting magnitude to the star's brightness.  At 60- to 260-day intervals, U Gem brightens quickly (taking 24 to 48 hours) to about magnitude +8.2, and stays there for a week or two --- you should have no trouble identifying it then, either in Cambridge or at Wallace!  A finder chart appears in *Burnham's Celestial Handbook, Vol.2*} on page 930, along with a plan of attack on page 925. Who will be the first to see U~Gem if it brightens for us this term?

### *4.5 Satellite Observations*

Passages of the HST spacecraft and International Space Station (ISS) can be visible sometime during the couple hours following the end of twilight.  It's visible from our location with a LX200 at low power provided you're looking in precisely the right place at the right time; it takes only 1 to 2 seconds to pass through the field.  Due to atmospheric drag and other effects constantly affecting the orbit, accurate finder charts cannot be prepared until the day of the planned observations.  Online sites will also give observation predictions for the Boston area.

# 5 Charts and Tables
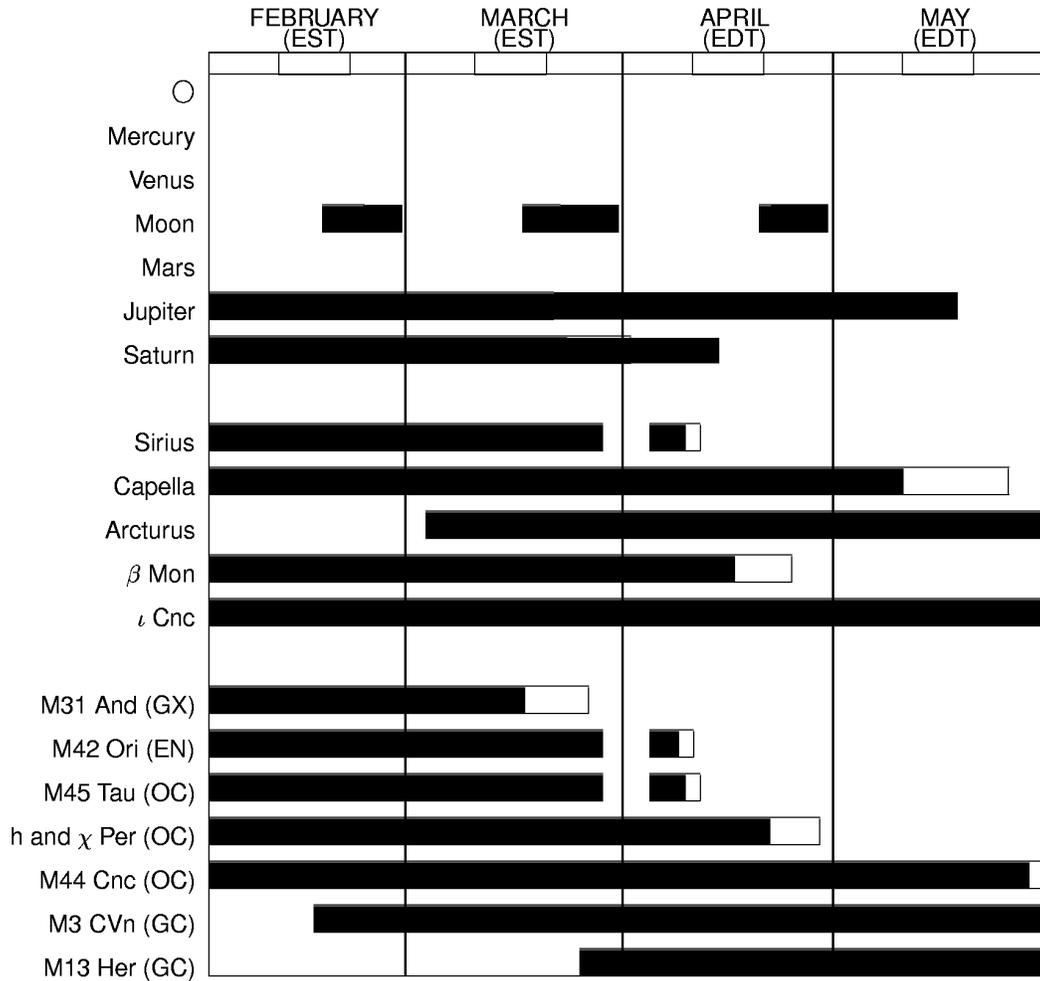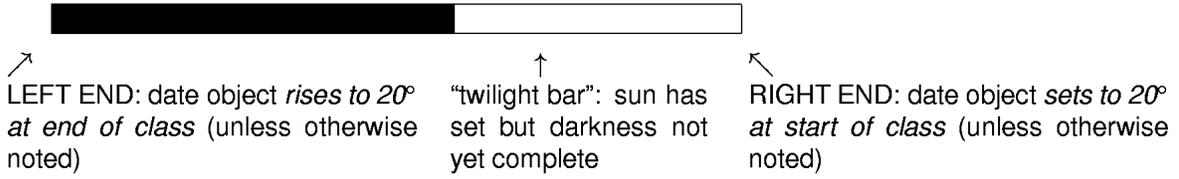
## 5.1 Object Information Table

Items in **bold** indicate well-known objects of special interest. Visibility information appears on pages 13 and 14. Note that coordinates given here for objects are for equator and equinox J2000.0.

Description key: EN = emission nebula   PN = planetary nebula
GC = globular cluster   OC = open cluster: mag. given as "brightest member (integrated)"
GX = galaxy   VS= variable star

| Object | Con. | RA2000 | Dec2000 | mvisual | Type | | Description |
|--------|------|--------|---------|---------|------|---|-------------|
| B Per | Per | $3^h08^m10^s.1$ | +40°57'.3 | ~2 | VS | □ | |
| ζ Gem | Gem | $7^h04^m07^s$ | +20°34'.1 | 3.7-4.2 | VS | ◇ | |
| HU Tau | Tau | $4^h38^m16^s$ | +20°41'.0 | 5.9-6.7 | VS | □ | |
| U Gem | Gem | $7^h55^m05^s$ | +22°00'.2 | 8.2-14.9 | VS | ◇ | |
| VZ Cnc | Cnc | $8^h40^m52^s$ | +9°49'.5 | 7.2-7.9 | VS | ◇ | |
| h Per | Per | $2^h19.^m0$ | +57°09' | 7 (4.3) | OC | ○ | half of the Double Cluster |
| χ Per | Per | $2^h22.^m4$ | +57°07' | 7 (4.3) | OC | ○ | the other half; h's buddy |
| NGC2244 | Mon | $6^h32.^m3$ | +4°51' | 7 (5.2) | OC | □ | Rosette Nebula cluster |
| NGC2419 | Lyn | $7^h38.^m1$ | +38°52' | 10.3 | GC | ◇ | |
| NGC7635 | Cas | $23^h20.^m7$ | +61°12' | 6.9 | EN | □ | Bubble Nebula |
| M1 | Tau | $5^h34.^m5$ | +22°02' | 8.4 | EN | □ | Crab Nebula |
| M3 | CVn | $13^h42.^m1$ | +28°23' | 6.3 | GC | ○ | |
| M5 | Ser | $15^h18.^m5$ | +2°06' | 6.1 | GC | □ | |
| M13 | Her | $16^h41.^m7$ | +36°28' | 5.9 | GC | ○ | Hercules Cluster |
| M31 | And | $0^h42.^m7$ | +41°16' | 3.5 | GX | ○ | Andromeda Galaxy |
| M38 | Aur | $5^h28.^m7$ | +35°51' | 8 (7.0) | OC | □ | |
| M42 | Ori | $5^h35.^m4$ | -5°23' | 4 | EN | ○ | Orion Nebula |
| M44 | Cnc | $8^h40.^m1$ | +20°00' | 6 (3.9) | OC | ○ | Beehive Cluster |
| M45 | Tau | $3^h47.^m0$ | +24°07' | 3 (1.6) | OC | ○ | The Pleiades |
| M51 | CVn | $13^h29.^m9$ | +47°12' | 8.4 | GX | ◇ | Whirlpool Galaxy |
| M57 | Lyr | $18^h53.^m7$ | +33°02' | 9.0 | PN | □ | Ring Nebula |
| M64 | Com | $12^h56.^m7$ | +21°33' | 8.5 | GX | □ | Blackeye Galaxy |
| M65 | Leo | $11^h19.^m0$ | +13°05' | 9.4 | GX | ◇ | spiral galaxy |
| M66 | Leo | $11^h20.^m2$ | +12°59' | 9.0 | GX | ◇ | spiral galaxy |
| M81 | UMa | $9^h55.^m8$ | +69°03' | 7 0 | GX | □ | spiral galaxy |
| M82 | UMa | $9^h56.^m0$ | +69°41' | 8.4 | GX | ◇ | irregular galaxy |
| M92 | Her | $17^h17.^m1$ | +43°09' | 6.4 | GC | □ | |
| M97 | UMa | $11^h14.^m9$ | +55°00' | 11.1 | PN | ◇ | Owl Nebula |
| M103 | Cas | $1^h33.^m3$ | +60°43' | 9 (6.9) | OC | ◇ | |
| M104 | Vir | $12^h40.^m0$ | -11°38' | 8.3 | GX | □ | SombreroGalaxy |
| M107 | Oph | $16^h32.^m5$ | -13°04' | 9.2 | GC | ◇ | |

### 5.2 Visibility of Easy (○) Objects

Bar marks dates between which object is above 20° altitude *sometime* during class for our location.



↗
LEFT END: date object *rises to 20°* *at end of class* (unless otherwise noted)

↑
"twilight bar": sun has set but darkness not yet complete

↖
RIGHT END: date object *sets to 20°* *at start of class* (unless otherwise noted)



| | FEBRUARY (EST) | MARCH (EST) | APRIL (EDT) | MAY (EDT) |
|---|---|---|---|---|
| ○ | | | | |
| Mercury | | | | |
| Venus | | | | |
| Moon | | | | |
| Mars | | | | |
| Jupiter | | | | |
| Saturn | | | | |
| Sirius | | | | |
| Capella | | | | |
| Arcturus | | | | |
| β Mon | | | | |
| ι Cnc | | | | |
| M31 And (GX) | | | | |
| M42 Ori (EN) | | | | |
| M45 Tau (OC) | | | | |
| h and χ Per (OC) | | | | |
| M44 Cnc (OC) | | | | |
| M3 CVn (GC) | | | | |
| M13 Her (GC) | | | | |

### *5.3 Visibility of Intermediate (□) and Expert (◇) Objects*

| | FEBRUARY (EST) | MARCH (EST) | APRIL (EDT) | MAY (EDT) |
|---|---|---|---|---|

**□**

- *β* Per (var)
- HU Tau (var)
- NGC7635 (EN)
- M103 Cas (OC)
- Rosette Neb. (EN)
- M1 Tau (EN)
- M38 Aur (OC)
- M64 Com (GX)
- M81 UMa (GX)
- M104 Vir (GX)
- M92 Her (GC)
- M5 Ser (GC)
- M57 Lyr (PN)

**◇**

- Uranus
- Neptune
- Juno
- Vesta
- NGC2419 (GC)
- M65 Leo (GX)
- M66 Leo (GX)
- M97 UMa (PN)
- M51 CVn (GX)
- M82 UMa (GX)
- M107 Oph (GC)

- *ζ* Gem (var)
- U Gem (var)
- VZ Cnc (var)