

**ASTR 511 OBSERVING LABORATORY I**  
**Visual Observations with the McCormick 6-in and 10-in Telescopes**

DUE FRIDAY SEPTEMBER 19

**Purpose:** To become familiar with basic observing procedures by making visual observations through the small McCormick telescopes.

**Preparation:**

1. Read the sections in the *Observatory Manual* on the use of the Doghouse, the 6-in Clark refractor, and the 10-in Meade.
2. Read the ASTR 511 handout "Hints on Observing".
3. If you do not already have experience observing with small telescopes, you should read relevant parts of the ASTR 130 Manual, which is linked to the ASTR 511 Lab web page. The most useful sections are probably the parts on finding targets and general observing technique in the chapter "Introduction to Small Telescopes" and Appendices B, C, and E. You need to know how to compute Hour Angle to find fainter targets with the 6-in telescope.
4. Hardcopies of the Appendix section giving suggestions on filling out standard observing forms will be handed out. You can download a PDF master for the observing forms from the ASTR 511 Lab page. Make photocopies to use as data sheets for your drawings of targets required in the lab. You can ignore the fields "features to observe," "first visible - last visible," and "TA initials." Make a finding chart only if necessary (fainter or confused targets).
5. Get checked out on each telescope by TA Peter Frinchaboy. Get Observatory keys from Jackie.
6. Remember that you must reserve the telescopes using the *Observatory Calendar* page linked from the ASTR 511 home page. By agreement with ASTR 313, normal ASTR 511 observing hours are after 11:30 PM, although any time slot is open to you if it not reserved by 24 hours in advance. Open seven days a week.

**Equipment**

1. A lab notebook or other means of recording your observations. Bring photocopies of the standard data sheet for drawings. You will be asked to turn in the original data sheets.
2. *Norton's Star Atlas* or some other source of coordinate lists and finding charts for the target objects listed below.
3. A flashlight with a red filter, a watch (a stop-watch function would be useful), a mm ruler, and other equipment as appropriate; see "Hints" for hints. A clipboard will prove very useful for the drawings.

**General Procedure**

1. You can work in groups, or in smaller subsets. But do **not** work alone.
2. You will need a reasonably clear night with little Moon. You can use less than optimum nights for practice or brighter targets (recommended so you don't waste time on subsequent good nights).

3. *Each student must do all parts of the lab and keep separate records.*
4. For each night you observe, you should record sky conditions (cloud cover, transparency, seeing, sky brightness, wind, temperature) and other pertinent comments on performance of the telescope, etc.
5. Some steps in the procedure involve the use of “aperture stop masks.” These are metal disks with circular holes which fit over the objective lens of the 6" refractor in order to simulate a smaller telescope. They fit into a special holder which can be mounted on the telescope.

## Specific Procedures

### A. FIELD OF VIEW

- A-1 Using the 6-in telescope, find a relatively bright star near the celestial equator. Altair is a good choice in the fall. Center it in the finder and, using a low power eyepiece, check that it is in the main telescope field and centered.
- A-2 Switch to a medium high power eyepiece (e.g. 20 mm) and recenter the star exactly by strongly defocusing the image until it becomes a huge donut that fills the eyepiece field. The blob of light will be easy to center. Clamp both the DEC and RA axes. Then refocus the star.
- A-3 Turn off the clockdrive and note in which direction the star drifts. (This is west, right?)
- A-4 Unclamp the telescope in RA but leave it clamped in DEC. Carefully move the star to the far eastern edge of the field (still clamped in DEC). Reclamp in RA. Now record the time it takes the star to drift across the entire field of view (in seconds). You want the star to move *across the full diameter of your field of view*. Record your estimate of the measurement uncertainty in the drift time.  
  
Repeat this measurement once and record the time.
- A-5 Repeat the whole procedure, starting with (A-2), to this point (for a total of 4 drift measures).
- A-6 Record the eyepiece focal length, and measure (with a mm ruler) the diameter of the eyepiece lens. Estimate the uncertainty in this measure.
- A-6 Place the 3-inch aperture stop mask over the telescope’s objective. Make a single field drift measurement to confirm that the size of the field of view does not depend on the aperture of the telescope.

### B. SEEING

- B-1 Using the 6-in, set on a moderately bright binary star with known separation in the 5-15'' range. Mizar ( $\zeta$  Ursa Major), with 15'' separation is a good choice most of the year. (Nearby Mizar is the 4<sup>th</sup> magnitude star Alcor, which is physically unassociated with Mizar and 12' distant.)  $\gamma$  Delphini is more useful in the early Fall.
- B-2 Draw the field surrounding the binary, indicating the angular scale, which direction is North, and which is East. (If you move the telescope in a particular direction, e.g. North, the stars in the field will move in the opposite direction.) See suggestions for making such drawings in the extracted Appendix from the ASTR 130 Manual.
- B-3 Switch to higher power and estimate the diameter of the seeing disk in arc-seconds by comparing the image sizes of the components to their separation (averaged over  $\sim 1$  minute). Estimate the uncertainty in the diameter measurement. Make a note as to whether

it is reasonably stable or variable. Repeat the measurement at least once later in the observing session to check for changes in the seeing. Record the “zenith distance” of each measurement—i.e. the distance in degrees between the zenith and the target star.

### C. LIMITING MAGNITUDE

C-1 Using the 6-in, set on the open cluster NGC 6913 (M29) in Cygnus (data sheet and finding chart attached; source: Hoag et al. *Publ. U.S. Naval Obs*, **17**, 346, 1961.). The brightest star in this cluster is at  $V = 8.4$ . Using a 25-mm eyepiece, determine the magnitude of the *faintest star* in the cluster which you can see in the telescope. You will have to match the finding chart to the field orientation in the telescope, then identify individual stars. One way to do this would be to number the stars on the finder chart from the brightest down and tick them off in order.

Be sure you are well dark-adapted and that all extraneous light sources are off. Use a red flashlight. Because the center of your eye’s retina is not the most sensitive to low light levels, practice using “averted vision” as you go down the list (i.e. look off to one side of the target of interest while concentrating your attention on the location of the target).

C-2 Place the 1-in aperture mask over the telescope objective and repeat the experiment.

### D. THE AIRY PATTERN

The Clark 6-in refractor lens is of high quality, and this telescope is diffraction-limited. The point-spread-function (PSF) of a telescope in the diffraction limit is called the *Airy pattern*. In class I quoted the diameter of the PSF at  $5500 \text{ \AA}$  as  $\sim 28''/D$ , where  $D$  is the diameter of the telescope objective in cm; this expression yields  $1.8''$  for the 6-in. This is actually the diameter of the first minimum in the PSF, which surrounds the central core of light called the “Airy disk.” However, the PSF has a series of alternating bright and dark rings extending to larger radii.

Under good seeing conditions, you should be able to detect at least the first bright Airy ring with the Clark refractor. The first ring has a total flux of about 8% of that in the Airy disk. Seeing may be a difficulty, but for a small telescope like this, the first order effect of moderate seeing is to shift a stellar image wholesale, rather than blur it (as would be the case in, say, the 40-in). The object of this experiment is to measure the size of the first Airy ring and compare it with theory.

D-1 Center the telescope on Vega ( $V = 0.03$ ) using a fairly high-power eyepiece. Then, replace the normal eyepiece with the illuminated reticle and a Barlow lens. Each division of the linear reticle corresponds to  $11.27''$  when used without a Barlow lens,  $5.64''$  when used with the  $2\times$  Barlow, or  $3.75''$  when used with the  $3\times$  Barlow.

D-2 Attempt to detect the first bright Airy ring. Try different aperture masks, as its appearance will change with the mask used. Pick any mask size where the ring can be measured. Record the mask opening diameter, and measure the angular diameter of the ring with the reticle. If you can measure the ring with the full 6-in aperture, do so.

### E. FIELD DRAWINGS

E-1 Using either telescope, observe Mars and any 4 of the other targets listed below (i.e. five targets total). *Write a brief, but careful, description of each and make a drawing of the field.*

Review the suggestions for making good drawings in the ASTR 130 Manual. Use the standard forms. Mark the N and E directions on each drawing. Use different eyepieces as appropriate; note which is used. The extended objects will be difficult to see if clouds are around or if the Moon is more than half full. For fainter objects, again use averted vision. It

is a good idea to practice both boresight pointing and RA/DEC acquisition while working through this list.

Coordinates and a rough map for the Messier (“M”) objects are attached. Use Norton’s or any other handy source (e.g. the Web) for the other targets.

Mars  
M13  
 $\alpha$  Hercules  
 $\epsilon$  Lyrae  
M11  
M57  
 $\beta$  Cygni  
19 Piscium  
M15  
M31  
M32  
M33 (difficult!)

## Writeup

### GENERAL

1. Briefly describe your observing sessions (sky conditions, group partners, any other pertinent information).
2. Turn in photocopies of all notes you made which were not on the standard forms. Turn in the *original* copies of the standard observing forms containing your drawings. Do not recopy or make any changes to those forms; however, you can transcribe the written description if it is difficult to read.

### FIELD OF VIEW

1. Collect and tabulate the drift times, the focal length and diameter of the eyepiece lens, and your estimate of the uncertainties in timing and diameter.
2. Determine the mean and the standard deviation of the timing measurements. The standard deviation,  $s$ , for this kind of sample is determined from:  $s^2 = \frac{1}{M-1} \sum_{i=1}^M (x_i - \bar{x})^2$ , where  $x_i$  is an individual measure,  $\bar{x}$  is the mean value, and  $M$  is the number of measurements. How does this value of  $s$  compare to your estimate of the timing uncertainty? Comment on any important discrepancy.
3. Determine the field of view by converting the mean crossing time to an angle in minutes of arc. What correction would you have had to make in this conversion if you had observed at a DEC of  $+50^\circ$  instead of on the equator?
4. The field of view of the telescope, as expected from geometrical optics, is the following: field diam =  $\arctan [d/(f_0 + f_1)]$ , where  $d$  is the diameter of the eyepiece lens,  $f_0$  is the focal length of the objective (1830-mm for the 6-in), and  $f_1$  is the focal length of the eyepiece. Compare your estimated field diameter with the expected value. If it doesn’t agree, try to reconcile the difference.

## SEEING

1. Provide all the specifics of your seeing measurements. Comment on any changes with time or other conditions. Good seeing at McCormick is 1–2". How do your measures compare?

## LIMITING MAGNITUDE

1. Briefly describe your method for determining the limiting magnitude and the results for both the full-aperture and 1-in aperture tests. If you think observing conditions (seeing, transparency) importantly affected the measures, comment on that.
2. How do the limiting magnitudes you determined compare with those expected if you assume the system sensitivity is proportional to the area of the objective and if the threshold for detection by the average person's naked eye under good observing conditions is 5<sup>th</sup> mag? Give, and justify, estimates for the uncertainty in the limiting magnitude observation and prediction. Reconcile any important discrepancy between expectations and the real world.

## AIRY PATTERN

1. Provide all the specifics of your measurements of the Airy pattern.
2. Compare your results to theory: the first minimum in the Airy pattern occurs at an angular radius of  $1.22\lambda/D$  radians, and the first bright ring occurs at an angular radius of  $1.63\lambda/D$  radians, where  $D$  is the diameter of the objective lens.