

A Guide to Scientific Presentation (Your Lab Write-Ups)

While most students will have had experience writing up lab reports from high school science courses, for some students this may be the first time they have been asked to present the results of an experiment according to the standard structure adopted by most scientists for reporting research. Therefore, in this lab I will give you both a general outline of what is expected for lab write-ups in this class, but also specific examples relating to the work in this first lab.

While I will not give you *everything* that should be included in your first lab write-up, enough will be given that you can adopt much of the skeletal structure given here and need only fill in details around it. However, do not just hand back this guide with notes written on it! Rewrite any of the following guide that you adopt into your own version of the report. Note also that you are expected to supply your *own* data for this work! All reports are expected to be typed or word-processed, with graphs and figures inserted in the proper place or clearly referenced from the text of your report.

If the report style that follows seems mystifying or even arcane, I invite you to spend some time leafing through scientific journals (e.g., *The Astrophysical Journal Letters*) to see that, in general, the approach we are requesting here is the same as that followed in the professional literature.

You should keep this guide to writing up lab reports for use throughout the semester.

The basic structure of your lab reports should be as follows:

1. **COVER PAGE:** Somewhere near the beginning of the Lab, perhaps on a cover page, list your name, your group name (e.g., "Group 1"), and the names of the people in the group with whom you took (and reduced/analyzed) the data. In labs where you will take images or other data, you should also list where those data are stored.
2. **A PURPOSE:** What is the *scientific reason* for undertaking the lab activities? In a professional context, the scientist would have no problem writing down the purpose of an experiment because he/she will have been motivated to do it by some burning question or hypothesis they want to answer. In this class, however, where you are being given a set of activities to do, it may not seem so obvious at the onset what the purpose is. However, by reading through the lab before doing the experiment and then undertaking the activities it should become obvious what are the fundamental scientific points we are trying to have you address. What you put down for the "Purpose" section of the lab report is thus an important indicator of how well you understood the scientific principles of the lab. We want to know that *YOU* know the *scientific* purpose of the lab.

Please do *not* put as your purpose something like "The purpose was to learn about telescopes". Yes, this is an ancillary goal of the lab, but we are trying to train you in the methods of professional scientists. A professional astronomer would never write in one of their research papers something like "We undertook the measurement of the radial velocity variations in the star Gamma Scorpheus because we wanted to learn how to use a spectrograph"!

Thus, for example, in the present lab, we would expect a purpose something like the following:

“The goal of this experiment is to determine: (1) the relationship between the field of view and magnification for different eyepieces used with a given telescope, and (2) the relationship between field of view and aperture diameter with a given telescope and eyepiece.”

3. **PROCEDURE:** This section of your report should be a simple description of the general procedures followed for each part of the experiment (please do not just reiterate the instructions of the lab, but rather explain briefly the general idea of what was done and why). The point of this part of the lab is to describe how the experiment was carried out at a level of detail sufficient for a colleague to reproduce the general procedures independently (though not necessarily copy exactly everything you did).

This does not need to be long, but it should give a general idea of what was done and the techniques used. You should also give information on the date(s) of observations and the name of the telescope and instrument used. Weather information (e.g., seeing conditions, clouds, moon phase) is also standard information astronomers give in their reports.

Here is an example of the kind of thing we are looking for:

“Observations were carried out on the night of UT 30 August 2012 using the 6-inch Clark refractor at McCormick Observatory and the Doghouse eyepiece and aperture stop set. The sky was not photometric;¹ some high cirrus clouds were noted, but we were still able to see bright stars. There was a crescent moon in the east. There was no wind and the atmosphere was calm, as evidenced by only slow scintillation² of stars.

To measure fields of view we used the transit time of stars across the center of the field of view through the eyepiece. For all measurements the star Altair was used. The transit times were then converted to field of view angles, after accounting for the declination of the star. The same observer (Jane Doe) made the observations of ingress and egress of the star from the field of view and signaled start and stop times to John Smith, who used a digital watch to time the transit.

We first measured the transit time (field of view) three times each for the 32 mm eyepiece, the 12.5 mm and the 7.4 mm eyepieces, respectively, on the 6-inch refractor, and one time for the finder scope. We then made three measurements of the transit time (field of view) using the 7.4 mm eyepiece but with the telescope stopped down to a 3-inch aperture. The results of these observations are presented below.”

4. **RESULTS:** In this section you should present all of the results of your observations and analysis, including the measured data, your calculations, graphs, and answers to the questions put forth in the Lab handout. **Please mark clearly in your write-up the number of the question (e.g., “Question 1” or “Point (3)”) when you answer it, to help make it easier for us to find your answers when grading this assignment.** We don’t want to hunt for your answers. Therefore, the structure of your results section should more or less mirror the order and outline of the lab instructions. Make sure to answer all of the questions asked in the lab. Please note:

- All data taken should be neatly tabulated when possible.

¹The term *photometric* means a sky where there is no cloud cover of any kind and accurate *photometry* of the source – measurement of the flux of the star can be done accurately. Conditions where there is a small amount of cloud cover, but it is still possible to work easily, are often described as *spectroscopic*.

²“twinkling”

- Show your calculations so that if there is a mistake in your answer, we can tell whether it was a simple math error or a more worrisome conceptual or measurement error.
- Graphs should have clearly labeled and graduated axes. Make sure the dependent variable (the part of the experiment you *measured*) is on the ordinate and the independent variable (the part of the experiment you *set* — e.g., the eyepiece focal length) is on the abscissa.
- If you include figures (e.g., graphs) and tables at the end of your report, each should be labeled clearly (e.g., “Figure 1”, “Table 3”) and referred to by that label in the text of your report.
- Please endeavor to record in your lab report only *significant digits*. Just because your calculator puts out six decimals of precision on some calculation does not mean that they are all meaningful and should be recorded. Have a good idea of to what precision you can trust your measurements and calculations. We will discuss more about significant digits as the semester progresses.

The skeleton of a results section for this particular lab might look something like this (obviously, you should use your own numbers and the ones provided here are just examples!):

Part 1: Field of View Versus Magnification

(Question 1) *The focal ratio of the Clark 6-inch refractor is given by the formula $f\# = F/D$ where F is the focal length of the objective and D is its diameter. Thus....(fill in your own words here).*

(Question 2) *According to Whittaker’s rule, the estimated upper limit to magnification is given by $m < D$ in mm. This would imply that the maximum useful resolution of the 6-inch telescope is $m = \dots$, though Roy & Clarke, in their book *Astronomy: Principles and Practice*, point out that with smaller apertures it is possible to exceed Whittaker’s rule. An estimate for the lower limit on useful magnification is given by....*

(Question 3) *The magnifications of the eyepieces can be found as follows:*

$$\text{magnification} = \frac{FL_{\text{objective}}}{FL_{\text{eyepiece}}} = \frac{1830\text{mm}}{FL_{\text{eyepiece}}},$$

from which magnifications of $73\times$ for the 25 mm eyepiece and $203\times$ for the 9 mm eyepiece are obtained. The exit pupils can be determined from

Table 2 below includes the expected magnification and exit pupil expected for each eyepiece. We note that all of the exit pupils are smaller than the typical human eye pupil (7 mm); this means....

(Question 4) *For all measurements of the field of view we used the star Altair, which has J2000.0 coordinates $(\alpha, \delta) = (19^{\text{h}}51^{\text{m}}, 8^{\circ}53')$. Table 1 shows the results of these measurements **(Question 5)**.*

*We estimate that the error on the Table 1 measurements is about 3 seconds with the 25 mm eyepiece, but maybe a little better (1 or 2 seconds) with the 9 mm eyepiece **(Question 6)** because the quickness of the star’s apparent motion makes it easier to tell when it is in and out of the field of view in the latter case. The error comes about because it is difficult to judge precisely when the star enters and exits the field of view,*

Table 1: Field of View Measurements for Different Eyepieces

| eyepiece | time (seconds) |
|-----------------|----------------|
| 9 mm (trial 1) | 51 |
| 9 mm (trial 2) | 50 |
| 9 mm (trial 3) | 52 |
| 25 mm (trial 1) | 140 |
| 25 mm (trial 2) | 143 |
| 25 mm (trial 3) | 138 |
| finder scope | 802 |

and there is an imprecision and delay in conveying the occurrence of those events to the timekeeper.

The average timing and standard deviation for the 9 mm eyepiece are 51 ± 1 seconds and for the 25 mm eyepiece are 140.3 ± 2.5 seconds (**Question 7**). The standard deviations calculated here are similar to our estimates above of about 1-2 seconds for the 9 mm eyepiece and 3 seconds for the 25 mm (**Question 7**).

The timings above can be converted to an angular field of view using the formula

$$FOV(\text{arc minutes}) = FOV(\text{minutes}) \times 15 \cos \delta .$$

(**Question 8**) Thus, we obtain a field of view of

$$51^s(1^m/60^s)(15)(\cos(8.9^\circ)) = 12.6 \text{ arc minutes}$$

for the 9 mm eyepiece and an error of

$$1^s(1^m/60^s)(15)(\cos(8.9^\circ)) = 0.2 \text{ arc minutes.}$$

Also,

$$140.3^s(1^m/60^s)(15)(\cos(8.9^\circ)) = 34.7 \text{ arc minutes}$$

for the 25 mm eyepiece and an error of

$$2.5^s(1^m/60^s)(15)(\cos(8.9^\circ)) = 0.6 \text{ arc minutes.}$$

Finally, for the finder scope one gets:

$$802^s(1^m/60^s)(15)(\cos(8.9^\circ)) = 198 \text{ arc minutes} = 3.3^\circ.$$

(**Question 9**) The derivation of this conversion formula is... (I can't give you all the answers!)

Thus the results of this experiment are as summarized in Table 2:

We note an interesting correlation in these data between magnification and field of view, which is that

Table 2: Field of View Versus Magnification

| <i>eyepiece</i> | <i>magnification</i> | <i>field of view (arcmin)</i> | <i>exit pupil (mm)</i> |
|-----------------|----------------------|-------------------------------|------------------------|
| 9 mm | 203 | 12.6 ± 0.2 | 0.75 |
| 25 mm | 73 | 34.7 ± 0.6 | 2.1 |

Part 2: Field of View Versus Magnification

(Question 10) *In the second part of the lab we check field of view timings using the same eyepiece but different telescope apertures. We use the 9 mm eyepiece for these measurements and find (using the 9 mm data for the 6-inch aperture from the table above) the results given in Table 3.*

Table 3: Field of View Measurements with Different Apertures and 9 mm Eyepiece

| <i>aperture (inches)</i> | <i>time (seconds)</i> |
|--------------------------|-----------------------|
| 6 (trial 1) | 51 |
| 6 (trial 2) | 50 |
| 6 (trial 3) | 52 |
| 3 (trial 1) | 53 |
| 3 (trial 2) | 50 |
| 3 (trial 3) | 51 |

For the 9 mm eyepiece and the 6 inch aperture the timing measured is 51 ± 1 sec and this corresponds to 12.6 ± 0.2 arcmin. For the 3 inch aperture we find an average time of 51.3 ± 1.5 seconds and this corresponds to

$$51.3^s(1^m/60^s)(15)(\cos(8.9^\circ)) = 12.7 \text{ arc minutes}$$

for the 9 mm eyepiece and an error of

$$1.5^s(1^m/60^s)(15)(\cos(8.9^\circ)) = 0.4 \text{ arc minutes.}$$

The results of this part of the experiment can be summarized as shown in Table 4.

(Question 11) *Interestingly, within the errors, the 3 inch aperture and the 6 inch aperture give the same result! Clearly there is no dependence of field of view on aperture of the telescope, though, as we found above, there is a dependence on the magnification.*

(Question 12) *The one aspect of the optical configuration that has not changed throughout our experiment is Thus, this aspect of the telescope cannot have had any bearing on the variations we observed with our set-up. This is as expected, because the variations we found in Tables 1 and 2 are due to*

Table 4: Field of View Versus Magnification

| aperture (inches) | field of view (arcmin) |
|-------------------|------------------------|
| 6 | 12.6 ± 0.2 |
| 3 | 12.7 ± 0.4 |

(Question 13) *The expected relationship between field of view and magnification is because ... We see that our data in Table 2 support this, because, as may be seen in our plot of field of view as a function of magnification shown in Figure 1, ... The relationship in our data is not exact, but this is because of the imprecision of our measurements. Within the 0.2 arcmin and 0.6 arcmin errors in our measured fields of view, the expected trend is found in our data.*

On the other hand we expect the aperture of the telescope at fixed focal length to have no bearing on the field of view because... Table 3 shows this to be the case, within the errors of the measurements.

(Question 14) *From our work we now see that lower magnifications correspond to larger fields of view. Thus, finder scopes are designed to have low magnification because this gives them higher fields of view, and this is important because...*

(Question 15) *The results of this experiment are subject to the imprecision in being able to gauge timings of stars crossing the field of view. There are several ways that our methodology may introduce measurement errors. One we discussed above is the uncertainty in determining precisely when the star enters and leaves the field of view and the delay in conveying this information from the observer to the timekeeper. This is complicated by the atmospheric effects on stars, which make them rapidly wander in their apparent position with time. Yet another source of error is...(I'll leave this for you to figure out!).*

5. CONCLUSION: What *scientific* conclusions do you draw from your experiments? Did your results conform to your expectations? Your conclusions sections should address the scientific questions raised in your PURPOSE section.

In this lab, the scientific conclusions might be something like:

We find that the relationship between field of view and magnification is... for eyepieces used on the same telescope. This is expected theoretically because...

We also find that there is no relationship between field of view and the aperture of the telescope, however this only holds for a telescope of fixed _____ and eyepiece because....

You might also note any other scientific findings that you did not expect in setting out to do the experiment, for example,

It was also noted that with higher magnification the stars appeared to move around a lot more. This is because the higher magnification also means that the image wander of the stars from the atmosphere is magnified.

6. Include a photocopy of the notes taken at the telescope. Note, this is to help us decipher potential problems with what you have done. We will NOT ordinarily look at this for grading, so do NOT use this photocopy to present your results. Please assemble your measurements and other important data into an orderly fashion (e.g., tables) for the RESULTS section.

Other tips and common mistakes in lab reports:

1. The word “data” is plural for the word “datum”. Thus “The data *are*...”, not “the data *is*...”. And, “We added one more datum to the analysis.”
2. Although your English and writing teachers probably have warned you about excessive use of passive voice, in scientific writing it is very common to use the passive voice to avoid excessive first person writing. Also, it is common to discuss your results in the present tense, e.g., “The timings are converted to angles...” rather than “The timings were converted to angles...”. The idea is that you are leading the reader through a process as if it is happening at the moment. Finally, it is common for science writers to use the “royal we” when they mean the first person singular “I”, though this is not mandatory.
3. Make sure to include all proper units along with your answers, e.g., not “51” but “51 seconds” for a timing measurement.
4. Make sure that your graphs, especially ones generated by a computer, do not include lines “connecting the dots”. In general, plots we make in this class will be “scatter plots”, where you will be plotting points corresponding to individual measurements of a dependent variable y versus an independent variable x (e.g., the measured field of view as a function of the magnification) in the hopes of finding some smooth trend (a line, or a curve) that might characterize a relationship between them. It is acceptable to attempt to find that smooth trend (for example, through *linear regression fitting*) and plot *that*, but you should not consider your points to have such good precision that every bump and wiggle in the trend of y with x is meaningful.
5. Be clear about the difference between minutes and seconds of time (which are used, for example, in right ascension) and arcminutes and arcseconds (which are used, for example, in declination). For that matter, be careful of the use of identical symbols ” for arcseconds and inches and ’ for arcminutes and feet. For this reason, astronomers tend to write out “inches” and “feet” to be clear. Often coordinates are written in the format “10:04” or “10:04:21”, and in this case it is assumed (from the context) that the first number is hours (right ascension) or degrees (declination), the second number is minutes of time (right ascension) or arcminutes (declination), etc.
6. Please make use of spell and grammar checkers on your computer whenever possible!!