FOR THE STUDENT

Laboratory Objective

To many of us ASTRONOMY is a fascinating subject. It has mystified humanity for many centuries for various reasons. Some people are just plain curious about the world/universe we live. Historically, ASTRONOMY has its origin in farming, philosophy, religion and astrology. Regardless of individual motives, the main foundation of ASTRONOMY is to observe the sky and to interpret it.

Have you ever wondered how scientists make discoveries? Have you ever wondered how we can tell anything about stars and galaxies that are so far, far away that we'll never be able to go there and personally explore them? This laboratory will provide you with some insights (hopefully!) of *how* astronomy is done. The basis of all science lies in experimenting and testing – after all that's how science was discovered! And you will be challenged to make some of these discoveries yourself. These labs are intended to give you a flavor of scientific methodology, and to convince yourselves (!!!) how it all works. And one day, when you read articles the *New York Times* or any science magazine, you will hopefully understand how those conclusions were reached – or better yet – be able to *judge* for yourselves whether or not those conclusions are feasible! Don't believe anything you hear or read; think about it first, and if you can, test it yourself!

The emphasis of these laboratories lies in *experimenting* and *understanding* the scientific principles and fundamental laws of PHYSICS and ASTRONOMY, or actually, of the world around you. Science is not magic – anybody can understand scientific principles, provided you *learn **how** to think scientifically*. (This is comparable to learning how to swim: it is not a gift you are born with – you have to *learn* to swim). If you have had difficulties with Science and/or Mathematics in the past, chances are that you do not know how to go about solving scientific problems – you may never have learned it. Or put differently – you may not have been taught how to do science effectively, probably not even due to a mistake of your own. The Labs are designed to help you learn how to do science and think scientifically. Please see this as a challenge. Initially it might not come naturally, but it can certainly be learned (that is – provided you do the work; *including* the thinking, because thinking really ***is*** hard work!). So give it a try – who knows – you might even surprise yourself!

Math and Formulae

The main stress is on the conceptual understanding of the laboratories. Some basic knowledge of MATH is essential, but it is limited to straightforward algebra with a whiff of trigonometry. Physical principles will be explained as we go along. The focus is not on using formulae and mindlessly typing numbers into your calculator, it is on understanding scientific principles. Often, you will be asked to explain *in words* how to go about solving particular problems. You will almost always be asked to elaborate on your results. You will probably find that the "fine art of writing" (without using math) poses a larger challenge. After all, what good are results if we cannot *communicate* their meaning?

The TOOLKIT summarizes some of the basic material that you'll need in this lab. Don't panic if you don't know all the material yet; you have the entire semester to learn it! The TOOLKIT is intended as a *reference manual* and can be used in the tests (in other word you will not need to memorize formulae, but you will have to know what they mean and how to use them).

Please do your best to figure things out on your own or with your partner before asking for help. You will find this course much more enjoyable if you do, since you will have achieved something yourself. In the process, you will stretch your mind. And after all, isn't that why you're here?

How to succeed in the Labs

Please make sure you understand why you are doing what. [Otherwise spending two or three hours in lab is a total wait of YOUR time!] If you are uncertain, please ask – our initiative is to help you understand the material. We will not give away answers, but we will do our best to guide you to the answers. [From our point of view just telling you the answers would be much easier, but this would not contribute towards YOUR understanding of the material].

Work in groups, and discuss the laboratories with you partner. You'll find that figuring out things together and bouncing ideas to and thro will make the lab much more enjoyable. Besides, this is a very important part in doing science. Articulating your arguments really does help you understand the material, and if one partner needs additional explaining, please take this opportunity to practice. Apart from a deeper understanding of the problem, it might also give you a sense of achievement.

If you are uncertain how to proceed with the experiment, ask – but please read the instructions before asking; you might figure out things on your own. And please, do not sit around waiting for an instructor to stop by – ask for help. Staring holes into the ceiling or chatting with your partner will not help you finish the lab.

Time Management – Suggestions

★ Please arrive on time and start with the lab immediately. Do not sit around doing nothing.

★ Please come prepared! Do the Pre-Lab. You might also find it useful to skim over the Main Lab. If you miss doing the Pre-Lab you will find that you will **not finish** the Lab in the **allocated** time!

★ Read the suggestions of how to **BUDGET** your time during the Labs.

★ Time Management is the key to success. For **EACH hour** in Lab expect to do **TWO hours** at home.

Rules

★ Please arrive **ON TIME** for the labs!!! Introductions to labs **will NOT be repeated**.

★ Please **turn off cell phones** during the lab! (Otherwise you have to donate $1 for the Post-Test-Doughnut-Kitty – this is not a joke.)

★ Please **do not eat** or drink in Lab.

★ Work in groups of two, and if need be in groups of three. Four is not allowed.

★ Attendance is mandatory. Missed labs **CANNOT** be rescheduled. Although 'do-at-home' labs are available in some cases, these are intentionally made to be more difficult and longer.

★ Although you are encouraged to work in groups, your answers should be in your ***own*** words, and your lab reports should be done ***individually***.

★ Pre-Labs due at the BEGINNING of the lab. Pre-Labs done in class will NOT be accepted.

★ Lab reports including the main lab are due one week after the laboratory sessions. Late reports will receive a 25% penalty for each week they are late.

★ If you have questions – **please *ask*!** Don't wait until the exams – or until after the exams.

Homework

★ **BEFORE THE LAB:** Please do the PRELAB *before* you come to lab (*the PRELAB is worth 15% of your lab grade*). You might also find it (*very!*) helpful to skim over the rest of the lab.

★ **AFTER THE LAB:** Finish all the calculations, answer all questions, and submit the **LAB REPORT**. The completed lab, including the report, is due one week after the lab is done in the laboratory. Late reports will receive a 25% penalty for each week they are late.

Important: Please hand in **CLEAN** lab reports. They do not have to be typewritten, but they should be legible, tidy and comprehensible. Otherwise, the labs will be returned – ungraded!

Tests and Grading

Test Format and Focus: The tests will consist mostly of short questions and essays. There will be NO multiple-choice questions. You will be tested on your general understanding of the material. Knowing mundane facts is not as important as showing *how* you arrive at your final conclusions. When you work for tests, make sure you always know why you did what. Concentrate on understanding concepts, not facts. Always articulate your points clearly. Badly phrased arguments will only earn you partial credit. There will be some calculations in the test, but please focus on *how* to solve the problems. You will not need to memorize formulae – these will be listed in the Toolkit (which you can use during tests). Also think about the final answers – if you determine that the size of the entire universe is 1 cubic centimeter, you have probably made an arithmetic slip somewhere. If you do not have time to find the slip, please state that there is one somewhere. This will earn you partial credit. When you get stuck doing the Math always explain *in words* how to proceed to get to the solution. Again, this will earn you partial credit. The main focus on tests is on conceptual thinking and scientific arguing.

Tests	Midterm	15%	material: *first 6* labs	40%	
	Final	25%	material: *last 6* labs		
Labs	PRE-LABS	15%	of 11 labs	60%	
	Lab Reports	45%	of 12 labs		

★ Doing well in the labs alone is not sufficient. (1) The tests constitute ~half of your grade [Make sure you thoroughly understand the labs (particularly the scientific concepts)!] (2) The pre-labs constitute ~one third of the grade of the main lab.

★ **Copying** in tests results in an "F". (Everybody will be reseated during the tests.)

★ There are **NO make-up exams**, unless you bring a documented excuse ***PRIOR*** to the exam.

★ The exams will test the material of **ALL** scheduled labs – if you miss a lab, it will be your responsibility to catch up and learn the material.

★ If you miss labs, do the take-home versions – otherwise you forfeit 5% of your grade. [Two missed labs reduce your final grade by one whole letter grade.]

SAMPLE LABORATORY REPORT

TITLE OF REPORT

Your Name, Date, and Affiliation (i.e., Department and School)

Abstract

Summarize the objective of the lab, make a short comment on the methodology, list your basic results, provide explanations of these results, and make one or two concluding remarks. [Be concise — one paragraph is enough — but make sure you describe the entire the lab. The abstract is intended to provide all relevant information and help the reader decide whether or not to read the remaining 10 to 15 pages.]

Main Report

1. Introduction

State the objective of the lab exercise. Provide the reader with background information – summarize the basic principle(s) and offer relevant information you think is critical in carrying out and understanding this lab (including formulae). Mention what is known already, how this lab fits into the big picture, why you are doing it (besides the fact that it's required ☺), and how it will impact on your understanding of the material. [Write one or two paragraphs – remember a paragraph is more than two sentences.]

2. Experimental Setup & Procedure

Give a narrative description of what you did. First **describe** the apparatus itself, including any other equipment you used. You many include a drawing of the setup to complement your description. Second, explain **how** you made the observations. Do not rewrite the instructions given in the handout – explain what did you do, how did you did it, and why you did it that way.

3. Data Presentation & Analysis

Present your data in the form of tables (including the uncertainty in the data – after all you want to convince the reader that you have solid results). Guide the reader to make it easier to look at the tables. Next analyze the data and do calculations (explain the relevant parts of your calculations, list the formulae you used). Do not write down all steps, but provide enough information so that the reader will be able to check your numbers. Present the final results in a logical and convincing manner. You'll find that **graphs** and **figures** are extremely useful! Summarize the results **in words**.

4. Interpretation & Conclusion

Draw conclusions from the observations and offer a connection to stated objectives of the lab. Restate the main results, discuss the accuracy of results and offer suggestions for improving the observations. Provide a thorough explanation of the results. What do they indicate to you? What do they mean? How do your results compare to those of other scientists? Which conclusions can you draw from your results? How do your conclusions help in understanding the big picture of what you are doing? Go *beyond* this lab – at this stage are allowed to speculate, perhaps even propose a model to impress your peers. Finally summarize the global conclusions, including open questions, and suggest how to continue this study.

5. References

List the literature you used to describe and understand this lab. List the references alphabetically (or numerically if you prefer), and refer to them throughout the report.

LITERATURE REVIEW ON ASTRONOMY OBSERVATIONS*

Format: The term paper must be based on some appropriate (ask instructor) subject dealt with in your course. The term paper is to be FOURTEEN pages, typed, double-spaced not counting any diagrams, footnotes or bibliography (use the word processors in the computer center or library).

Resources: Textbooks, Magazines and the Web. Textbooks **alone** are not acceptable sources for the paper. You should read articles in popular astronomy magazines (e.g., Sky and Telescope, Astronomy, etc), in newspapers (e.g., Monday-Science-Section of the New York Times, etc), and on the Web. You may even red professional journals, if you wish.

Rules: You are not allowed to copy written articles or cut and paste paragraphs or sentences into your report. Everything should be in your **own** words. You may copy pictures if you reference them.

Suggestion: Make notes while you doing the background reading. When you are done with the bulk of the reading review your own notes and think about them. Organize your thoughts and write an outline of your essay (show this outline to your instructor). Now start writing the essay using your notes. Focus on the main points of the topic, but make sure you include enough detail to support you points. Then briefly summarize these points and write your **own** conclusion.

Suggested Format

I) Title Page (Your Name and Title of Report) and Abstract

II) Introduction
   a. What are you going to talk about
   b. A general overview of the issue
   c. What the reader should expect

III) Body of the Report
   a) Review of Observations and Results
      i) List the relevant known facts and state scientific definitions
      ii) Description of observational setup and how to obtain the observations
      iii) List the results tables, itemize them or summarize them in paragraphs. Make sure you present the results in an informative manner: Illustrations and graphs are useful!
   b) Review of Discussion and Analysis
      i) Include inductive thinking used by author(s); i.e. the intuitive concepts that ultimately give rise to hypotheses from the information.
      ii) Then explain the deductive thinking used by author(s); i.e. the rigorous logical (verbal and/or mathematical) reasoning and where it leads from part a.
      iii) Generalizations: This is the probable conclusions drawn from the info of part a.
   c) **Your** Conclusion
      i) Summarize the paper
      ii) State your own opinions!
      iii) List potential applications of results
      iv) Final impressive statement(s)

IV) Bibliography (THESE ITEMS SHOULD BE REFERRED BY NUMBER IN THE REPORT)
   References (Works you used including important works used by authors)

* Provided by Irving Robbins

American Museum of Natural History Field Trip*

This optional field trip can count as two observation sessions or significant extra credit depending on report depth and length: Attach ticket stubs and/or receipts as proof of your visit. Be prepared to spend the day or at least 5 hrs there. When visiting the museum, pick up a floor plan map. You will explore in this trip the Rose Center for Earth and Space at the American Museum of Natural History at Central Park West and West 81st Street. The main highlights include the New Hayden Planetarium, "Big Bang Theater" and the Cullman Hall of the Universe. Take notes whenever possible and answer questions and prepare summaries of your experience as indicated below.

1. Visit and experience the space show at the Planetarium. Tickets for the space show can be reserved by calling *212 769 5200*.
   A. Summarize the science behind the show you see (1 or more full pages — take notes during the show when possible).
   B. What are the features that make this Planetarium and its Zeiss Star Projector unique.
2. Visit the bottom half of the Great Sphere and explore the "Big Bang Theater" — a dramatic re-creation of the origins of the universe.
   A. Discuss your findings about the beginning of time and space, and the dramatic, multisensory re-creation of the first moments of the universe.
3. Continue from the latter on a journey that chronicles the evolution of the universe by following the Cosmic Pathway — a sloping walkway that takes you through 13 billion years of cosmic evolution.
   A. Summarize the highlights of this walk.
   B. What is humanity's importance in this perspective?
4. The Cosmic Pathway leads you to the Hall of the Universe, on the bottom level of the Rose Center, underneath the sphere.
   A. Examine and study the Kinetic sculptures, computer visualizations, and dramatic projected images that illustrate the processes that led to the creation of our galaxy, stars, and planets. Note that the topics are presented in thematic clusters called zones.

Briefly answer the following questions about the modern discoveries of astrophysics.

A. How did the universe evolved into galaxies, stars, and planets?
B. How did the atoms from which we are made get created in cosmic events?
C. Where did the matter necessary for life come from?
D. Discuss what you find out about (supermassive) black holes?
E. Watch the video shown in an adjacent mini-theater and discuss the nature of the extreme forces of gravity and the warping of space & time found near a black hole.
F. Note the video sequence of two colliding galaxies that appears to hang in space above the Galaxies Zone, and discuss this phenomenon.
G. In the Stars Zone, the rare circumstance of an entire star exploding as a supernova is featured. Discuss this event.
H. The Planet Zone features the Willamette Meteorite. What is the significance of this ancient cosmic debris?
I. How does the "Ecosphere," found in this Hall answer questions about where life could exist in the universe and how we are searching for it?
J. From the "Astro Bulletin," summarize the latest news, and events from space — especially, what are the current space missions?

* Provided by Irving Robbins