ARIZONA STATE UNIVERSITY

GENERAL STUDIES COURSE PROPOSAL COVER FORM

(ONE COURSE PER FORM)

1.) DATE: **08/03/2013** | 2.) COMMUNITY COLLEGE: **Maricopa Co. Comm. College District**

3.) COURSE PROPOSED: Prefix: **AST** Number: **101** Title: **Survey of Astronomy** Credits: **3**

CROSS LISTED WITH: Prefix: Number: ; Prefix: Number: ; Prefix: Number: ;

Prefix: Number: ; Prefix: Number: ; Prefix: Number:

4.) COMMUNITY COLLEGE INITIATOR: **STEVEN MUTZ** PHONE: **480-423-6122**

FAX:

ELIGIBILITY: Courses must have a current Course Equivalency Guide (CEG) evaluation. Courses evaluated as NT (non-transferable are not eligible for the General Studies Program.

MANDATORY REVIEW:

☒ The above specified course is undergoing Mandatory Review for the following Core or Awareness Area (only one area is permitted; if a course meets more than one Core or Awareness Area, please submit a separate Mandatory Review Cover Form for each Area).

POLICY: The General Studies Council (GSC-T) Policies and Procedures requires the review of previously approved community college courses every five years, to verify that they continue to meet the requirements of Core or Awareness Areas already assigned to these courses. This review is also necessary as the General Studies program evolves.

AREA(S) PROPOSED COURSE WILL SERVE: A course may be proposed for more than one core or awareness area. Although a course may satisfy a core area requirement and an awareness area requirement concurrently, a course may not be used to satisfy requirements in two core or awareness areas simultaneously, even if approved for those areas. With departmental consent, an approved General Studies course may be counted toward both the General Studies requirements and the major program of study.

5.) PLEASE SELECT EITHER A CORE AREA OR AN AWARENESS AREA:

Core Areas: **Natural Sciences (SG)** Awareness Areas: **Select awareness area...**

6.) **On a separate sheet, please provide a description of how the course meets the specific criteria in the area for which the course is being proposed.**

7.) DOCUMENTATION REQUIRED

☒Course Description
☒Course Syllabus
☒Criteria Checklist for the area
☒Table of Contents from the textbook required and/or list or required readings/books
☒Description of how course meets criteria as stated in item 6.

8.) THIS COURSE CURRENTLY TRANSFERS TO ASU AS:

☐ DEC prefix
☒ Elective

Current General Studies designation(s): **AST 101/102: SG**

Effective date: **2013 Spring** Course Equivalency Guide

Is this a multi-section course? ☒ yes ☐ no

Is it governed by a common syllabus? ☒ yes ☐ no **District-wide course competencies/outline**

Chair/Director: **JOHN GRIFFITH** Chair/Director Signature: **Emailed approval to M. Chavira**

AGSC Action: Date action taken: ☐ Approved ☐ Disapproved

Effective Date:

ARIZONA STATE UNIVERSITY

GENERAL STUDIES COURSE PROPOSAL COVER FORM

(ONE COURSE PER FORM)

1.) DATE: **08/03/2013**	2.) COMMUNITY COLLEGE: **Maricopa Co. Comm. College District**

3.) COURSE PROPOSED: Prefix: **AST** Number: **102** Title: **Survey of Astronomy Laboratory** Credits: **1**

CROSS LISTED WITH: Prefix: Number: ; Prefix: Number: ; Prefix: Number: ;

Prefix: Number: ; Prefix: Number: ; Prefix: Number:

4.) COMMUNITY COLLEGE INITIATOR: **STEVEN MUTZ** PHONE: **480-423-6122**

FAX:

ELIGIBILITY: Courses must have a current Course Equivalency Guide (CEG) evaluation. Courses evaluated as NT (non-transferable are not eligible for the General Studies Program.

MANDATORY REVIEW:

☒ The above specified course is undergoing Mandatory Review for the following Core or Awareness Area (only one area is permitted; if a course meets more than one Core or Awareness Area, please submit a separate Mandatory Review Cover Form for each Area).

POLICY: The General Studies Council (GSC-T) Policies and Procedures requires the review of previously approved community college courses every five years, to verify that they continue to meet the requirements of Core or Awareness Areas already assigned to these courses. This review is also necessary as the General Studies program evolves.

AREA(S) PROPOSED COURSE WILL SERVE: A course may be proposed for more than one core or awareness area. Although a course may satisfy a core area requirement and an awareness area requirement concurrently, a course may not be used to satisfy requirements in two core or awareness areas simultaneously, even if approved for those areas. With departmental consent, an approved General Studies course may be counted toward both the General Studies requirements and the major program of study.

5.) PLEASE SELECT EITHER A CORE AREA OR AN AWARENESS AREA:

Core Areas: **Natural Sciences (SG)** Awareness Areas: **Select awareness area...**

6.) **On a separate sheet, please provide a description of how the course meets the specific criteria in the area for which the course is being proposed.**

7.) DOCUMENTATION REQUIRED

- ☒ Course Description
- ☒ Course Syllabus
- ☒ Criteria Checklist for the area
- ☒ Table of Contents from the textbook required and/or list or required readings/books
- ☒ Description of how course meets criteria as stated in item 6.

8.) THIS COURSE CURRENTLY TRANSFERS TO ASU AS:

- ☐ DEC prefix
- ☒ Elective

Current General Studies designation(s): **AST 101/102: SG**

Effective date: **2013 Spring** Course Equivalency Guide

Is this a multi-section course? ☒ yes ☐ no

Is it governed by a common syllabus? ☒ yes ☐ no **District-wide course competencies/outline**

Chair/Director: **JOHN GRIFFITH** Chair/Director Signature: **Emailed approval to M. Chavira**

AGSC Action: Date action taken: ☐ Approved ☐ Disapproved

Effective Date:

Proposer: Please complete the following section and attach appropriate documentation.

ASU--[SG] CRITERIA

I. - FOR ALL *GENERAL* [SG] NATURAL SCIENCES CORE AREA COURSES, THE FOLLOWING ARE CRITICAL CRITERIA AND MUST BE MET:

YES	NO		Identify Documentation Submitted
☒	☐	1. Course emphasizes the mastery of basic scientific principles and concepts.	Syllabus, Reading List, Lab Exercises, & Detailed Statement Supplement
☒	☐	2. Addresses knowledge of scientific method.	Syllabus, Reading List, Lab Exercises, & Detailed Statement Supplement
☒	☐	3. Includes coverage of the methods of scientific inquiry that characterize the particular discipline.	Syllabus, Reading List, Lab Exercises, & Detailed Statement Supplement
☒	☐	4. Addresses potential for uncertainty in scientific inquiry.	Syllabus, Reading List, Lab Exercises, & Detailed Statement Supplement
☒	☐	5. Illustrates the usefulness of mathematics in scientific description and reasoning.	Syllabus, Reading List, Lab Exercises, & Detailed Statement Supplement
☒	☐	6. Includes **weekly** laboratory and/or field sessions that provide hands-on exposure to scientific phenomena and methodology in the discipline, and enhance the learning of course material.	Syllabus, Reading List, Lab Exercises, & Detailed Statement Supplement
☒	☐	7. Students submit written reports of laboratory experiments for constructive evaluation by the instructor.	Syllabus, Reading List, Lab Exercises, & Detailed Statement Supplement
☒	☐	8. Course is general or introductory in nature, ordinarily at lower-division level; not a course with great depth or specificity.	Syllabus, Reading List, Lab Exercises, & Detailed Statement Supplement
II. - AT LEAST ONE OF THE ADDITIONAL CRITERIA THAT MUST BE MET WITHIN THE CONTEXT OF THE COURSE:			
☒	☐	A. Stresses understanding of the nature of basic scientific issues.	Syllabus, Reading List, Lab Exercises, & Detailed Statement Supplement
☒	☐	B. Develops appreciation of the scope and reality of limitations in scientific capabilities.	Syllabus, Reading List, Lab Exercises, & Detailed Statement Supplement

☒	☐	**C.** Discusses costs (time, human, financial) and risks of scientific inquiry.	Syllabus, Textbook TOC, Lab Book, & Detailed Statements Supplement

	[SG] REQUIREMENTS CANNOT BE MET BY COURSES:	
	• Presenting a qualitative survey of a discipline.	
	• Focusing on the impact of science on social, economic, or environmental issues.	
	• Focusing on a specific or limiting but in-depth theme suitable for upper-division majors.	

Course Prefix	Number	Title	Designation
AST AST	101 102	Survey of Astronomy Survey of Astronomy, Laboratory	SG

Explain in detail which student activities correspond to the specific designation criteria. Please use the following organizer to explain how the criteria are being met.

Criteria (from checksheet)	How course meets spirit (contextualize specific examples in next column)	Please provide detailed evidence of how course meets criteria (i.e., where in syllabus)
Course emphasizes the mastery of basic scientific principles and concepts.	Please see attached detailed statements supplement	Please see attached detailed statements supplement
Addresses knowledge of scientific method.	Please see attached detailed statements supplement	Please see attached detailed statements supplement
Includes coverage of the methods of scientific inquiry that characterize the particular discipline.	Please see attached detailed statements supplement	Please see attached detailed statements supplement
Addresses potential for uncertainty in scientific inquiry.	Please see attached detailed statements supplement	Please see attached detailed statements supplement
Illustrates the usefulness of mathematics in scientific description and reasoning.	Please see attached detailed statements supplement	Please see attached detailed statements supplement
Includes **weekly** laboratory and/or field sessions that provide hands-on exposure to scientific phenomena and methodology in the discipline, and enhance the learning of course material.	Please see attached detailed statements supplement	Please see attached detailed statements supplement
Students submit written reports of laboratory experiments for constructive evaluation by the instructor.	Please see attached detailed statements supplement	Please see attached detailed statements supplement
Course is general or introductory in nature, ordinarily at lower-division level; not a course with great depth or specificity.	Please see attached detailed statements supplement	Please see attached detailed statements supplement
Stresses understanding of the nature of basic scientific issues.	Please see attached detailed statements supplement	Please see attached detailed statements supplement
Develops appreciation of the scope and reality of limitations in scientific capabilities.	Please see attached detailed statements supplement	Please see attached detailed statements supplement
Discusses costs (time, human, financial) and risks of scientific inquiry.	Please see attached detailed statements supplement	Please see attached detailed statements supplement

AST 101/102 Proposal for SG: Detailed Statements Supplement

PART I: For all *general* (SG) natural sciences core area courses, the following are critical criteria and must be met:

A. **Course emphasizes the mastery of basic scientific principles and concepts**

   a. How course meets spirit:

   The course demonstrates the success of using scientific principles in modern astronomy. The *Historical Astronomy* section of the course contains many examples of the pitfalls of not using the scientific method. Throughout the course, students are exposed to various aspects of the Copernican Principle: that the same laws of physics that work here, apply everywhere in the Universe. With that, students learn what we know about the Earth can be used to begin to understand the other Terrestrial planets, what we know about the Sun can be used to begin to understand the other stars, the discovery of the Hubble Law has implications for our Universe and its evolution, and so on.

   While there are no prerequisites for this course, some mathematical skills are necessary to understand and appreciate *some topics (e.g.,* blackbody radiation and its relevance to understanding the stars, Kepler's Laws of Planetary Motion, etc.). The mathematics, when needed, are taught alongside the scientific concepts,. This technique is used extensively for the AST 102 laboratory coursework, too - as most lab exercises are quantitative by necessity.

   b. Course competencies met:

   Basic science principles and concepts are developed especially as part of the exploration of the following competencies:

   -- Apply the scientific method and other critical thinking models to astronomical phenomena for hypotheses development, experimental design, data acquisition, and data analysis

   -- Outline the history of astronomical thought

   -- Describe instruments used to detect radiation from the various portions of the electromagnetic spectrum

   -- Compare and contrast the physical properties of the planets.

   -- Explain the significance of the Hertzsprung-Russell diagram.

   -- Explain the significance of Hubble's Law.

   c. Detailed evidence of how course meets criterion:

   Please note that here and throughout this document, only representative examples have been detailed; these are only a few of the examples used during the course.

   i. Syllabus: Page 1

ii. Reading List: I.F., II.A, B, C, D, , III.A-G, VII.A-D, VIIII.A-L, IX.A-K, XIII.C-F, XX.C&E

iii. Lecture: "Ancient Astronomy", "Ptolemy/Copernicus/Tycho Brahe", "Kepler/Galileo/Newton/The Scientific Method", "Solar System Overview", "The H-R Diagram", "The Hubble Law/Quasars/Active Galaxies."

iv. Labs:

Lab 1: A Scale Model of the Solar System.

Lab 7: Telescopes and Optics

Lab 10: Sunspots

Lab 12: Galaxy Classification and the Hubble Law

B. Addresses knowledge of the scientific method

a. <u>How course meets spirit:</u>

Students are initially exposed to the scientific method during the first week of class when they are asked to provide a definition of "science" and "astronomy." Through a dialogue with the instructor, they are led to the modern definitions of "science" and "astronomy" and how knowledge is gained in modern science. During the historical astronomy portion of the class, the students are given a formal definition and exploration of the methodology of the scientific method. This is done in the historical context of the late Renaissance and the work of Galileo – the father of the modern scientific method. Students learn that most of the modern conveniences and the extremely high standard of living that they enjoy are direct results of the application of the scientific method.

b. <u>Course competencies met:</u>

As in "A" above, the scientific method is developed as part of the exploration of the core competencies listed for the course.

c. <u>Detailed evidence of how course meets criterion:</u>

i. Syllabus: Page 1

ii. Reading List: II.A, C, D.

iii. Lecture: "Kepler/Galileo/Newton/The Scientific Method"

iv. Labs:

Lab 1: Scale Model of the Solar System

Lab 5: Kepler's Laws

Lab 7: Telescopes and Optics

Lab 10: Sunspots

Long Term Lab Project: Sunrise/set Project

C. Includes coverage of the methods of scientific inquiry that characterize the particular discipline.

a. How course meets spirit:

As in all modern sciences, there are several methods of scientific inquiry that are indispensible parts of astronomy. To name just a few examples, astronomers use *comparative planetology* to understand better the processes that make our solar system's planets similar or different, use of the *H-R diagram* leads to understanding of the physical differences and similarities of the stars, *modeling the internal physics of the stars and comparing the results to observational data* gives astronomers an insight into the evolution of the stars, the study of *Cepheid Variable* stars has led to the ability to not only determine the distances to other galaxies for the first time, but has also enabled astronomers to determine the age of the Universe itself

b. Course competencies met:

- Compare and contrast the physical properties of the planets.
- Explain the significance of the Hertzsprung-Russell diagram.
- Describe the birth, life, and death of stars.
- Explain the significance of Hubble's Law

c. Detailed evidence of how course meets criterion:

i. Syllabus: Page 1
ii. Textbook: I.A, C-G, II.A-E, IV.A-D, VI-XXII
iii. Lecture: "The Night Sky", "Telescopes, Observatories", "The Nature of the Stars", "The H-R Diagram", "The Deaths of Low-Mass Stars/The Deaths of High-Mass Stars", "Cosmology", "Earthquake Slip" activity
iv. Labs:

Lab 5: Kepler's Laws
Lab 7: Telescopes and Optics
Lab 10: Sunspots
Lab 12: Galaxy Classification and the Hubble Law

D. Addresses potential for uncertainty in scientific inquiry

a. How course meets spirit:

In the science of astronomy, the potential for uncertainty is greater than in almost any other science. Students in AST 101 are treated to an object lesson in uncertainty while studying the historical timeline of modern astronomy. Previous ideas of the Universe and our place in it have proven to be drastically (and almost comically) wrong. Even today, our understanding of the scale and evolution of the Universe is replete with uncertainty (e.g., active galaxies). One of the most important yet least understood aspects of astronomy is the occurrence and prevalence of life throughout the Universe. Students are continuously cautioned about these and other uncertainties and our ability to make use of astronomical data to understand the Universe in light of these uncertainties.

AST 102 lab students are educated in measurement uncertainty and the limitations uncertainty imposes on the value of scientific data. Examples:

1. Telescope Optics lab - students construct a basic refracting telescope for which they estimate its magnification, and then compare their estimate to the calculated magnification.

2. Kepler's Laws lab – students attempt to verify Kepler's 2nd Law of equal areas swept out in equal time intervals using orbital data for Halley's comet. The students must explain the reasons for discrepancies between their results and the 2nd Law.

b. Course competencies met:

-- Outline the history of astronomical thought.
--Describe possible models which account for active galaxies.
--Describe current cosmological models and their implications on the past and the future.
--Explain the probability of extraterrestrial intelligence and the possibility of extraterrestrial communication.

c. Detailed evidence of how course meets criterion:

i. Syllabus: Page 1
ii. Reading List: I.D, F, G, IIA-D, IX.A-C, XIII.A-F, XIX.G, XXII.A-H
iii. Lecture: "Ancient Astronomy"," Ptolemy/Copernicus/Tycho Brahe", "Kepler/Galileo/Newton/The Scientific Method", "The Hubble Law/Quasars/Active Galaxies", "The Early Universe/Extraterrestrial Life."
iv. Labs:
Lab 1: Scale Model of the Solar System
Lab 5: Kepler's Laws
Lab 7: Telescopes and Optics
Lab 12: Galaxy Classification and the Hubble Law

E. Illustrates the usefulness of mathematics in scientific description and reasoning.

a. How course meets spirit:

Mathematical principles are introduced to students beginning with the first lecture's overview of the metric system. Throughout the course, students must interpret graphs (Blackbody curves, the Hubble Law), understand relationships through equations (Kepler's laws of planetary motion, Blackbody radiation), and appreciate physical behaviors with the help of mathematical models (stellar evolution, the Hubble Law). In the AST 102 lab, students learn the indispensability of mathematics in understanding astronomical data. Examples:

1. Deriving a mathematical scale model of the Solar System to develop an intuitive understanding of its true scale.

2. Calculating the magnification of a simple refracting telescope using the Lensmaker's Formula.

3. Using Kepler's laws of planetary motion to derive orbital parameters for orbiting bodies within our Solar System.

b. Course competencies met:

-- Outline the history of astronomical thought.

-- Describe in terms of energy, wavelength, and frequency the various portions of the electromagnetic spectrum.

-- Describe the birth, life, and death of stars.

-- Explain the significance of Hubble's Law

c. Detailed evidence of how course meets criterion:

i. AST 102 Syllabus: Page 1, 2

ii. Reading List: I.B, C, E, G, II.A-E, III.A-G, XIII.A-F, XIV.A, B, E, F, G, XVII.A-I, XX.A, D, E, XXII.A-F

iii. Lecture: "Introduction/Metric System", "The Night Sky", "Kepler/Galileo/Newton/The Scientific Method"," Light/EM Radiation", "Telescopes/Observatories", "Spectroscopy/Kirchoff's Laws/The Doppler Effect"," The Nature of the Stars", "The H-R Diagram", "The Deaths of Low-Mass Stars", "The Deaths of High-Mass Stars", "Relativity", " Hubble Classification/The Hubble Law", "Cosmology"," The Fate of the Universe"," The Early Universe."

iv. Labs:

Lab 1: Scale Model of the Solar System

Lab 2: Celestial Coordinate Systems

Lab 5: Kepler's Laws

Lab 7: Telescopes and Optics

Lab 9: Determining the Altitude of a Meteor

Lab 10:Sunspots

Lab 11: Stellar Parallax

F. Includes weekly laboratory and/or field sessions that provide hands-on exposure to scientific phenomena and methodology in the discipline, and enhance the learning of course material.

a. How course meets spirit:

Students must take the AST 102 course in addition to the AST 101 course to satisfy the [SG] general science requirement. AST 102 weekly laboratory activities are designed to correlate with, and support, the AST 101 lecture material. These laboratory activities are designed to give students an investigative experience complementing the concepts given them in AST 101.

AST 102 laboratory exercises require students to gather data and personally investigate the concepts presented in the labs. Students must gather data and make conclusions based on that data in the context of the lab subject matter. Students make use of real data, whether gathered on their own (e.g., Sunspot observations) or, if that is not practical (e.g., images of the Crab Nebula taken 34 years apart), given to them by the instructor.

b. Course competencies met:

-- Apply the scientific method and other critical thinking models to astronomical phenomena for hypotheses development, experimental design, data acquisition, and data analysis.

--Follow directions in completing laboratory exercises.

--Properly and safely use laboratory tools, e.g. calculator, computer, rulers, protractors, cameras, telescopes, magnifiers, maps, etc., for data acquisition, data analysis, or simulation.

c. Detailed evidence of how course meets criterion:

i. AST 102 Syllabus: Page 1, 2
ii. Reading List: I - XXII, all subsections
iii. Lecture: All lecture topics
iv. Labs:
Lab 1: Scale Model of the Solar System
Lab 2: Celestial Coordinates
Lab 3: Planetarium Exercise
Lab 4: Sundials
Lab 5: Kepler's Laws
Lab 6: The Moon's Landscape
Lab 7: Telescopes and Optics
Lab 8: Astronomy Magazine
Lab 9: Determining the Altitude of a Meteor
Lab 10: Sunspots
Lab 11: Stellar Parallax
Lab 12: Galaxy Classification and the Hubble Law
Long Term Lab Project: Sunrise/set Project

G. Students submit written reports of laboratory experiments for constructive evaluation by the instructor.

a. How course meets spirit:

The students work in a collaborative environment, working in teams to gather data. Students must, however, make all calculations and conclusions based on their results on their own. Students submit written reports, showing all observational data and calculations along with their conclusions. The instructor grades these reports and returns them to the students, reviewing any weaknesses or common problems. At the end of the semester, students take a written comprehensive lab final, reinforcing the students' understanding of the concepts presented during the semester.

b. Course competencies met:
-- Work effectively in collaborative groups.
--Write accurate and meaningful reports analyzing experiments, both qualitatively and quantitatively. See part "F" above for a list of competencies met by the laboratory experiences.

c. Detailed evidence of how course meets criterion:

i. AST 102 Syllabus: Page 1, 2
ii. Reading List: I – XXII, all subsections
iii. Lecture: All lecture topics
iv. Labs:
Lab 1: Scale Model of the Universe
Lab 2: Celestial Coordinates
Lab 3: Planetarium Exercise
Lab 4: Sundials
Lab 5: Kepler's Laws Lab 6: The Moon's Landscape
Lab 7: Telescopes and Optics
Lab 8: Astronomy Magazine
Lab 9: Determining the Altitude of a Meteor
Lab 10: Sunspots
Lab 11: Stellar Parallax
Lab 12: Galaxy Classification and the Hubble Law
Long Term Lab Project: Sunrise/set Project
Laboratory Final Exam

H. Course is general or introductory in nature, ordinarily at lower-division level; not a course with great depth or specificity.

a. How course meets spirit:
The course is designated as a "survey" course and is therefore general by design. It is intended for students with little or no mathematical or astronomical background. Any mathematical skills necessary for the course are taught and/or reviewed when needed during the course.

b. Course competencies met:
See the MCCCD Official Course Description:
"Survey of Astronomy for the nontechnical student. The history, content, and evolution

of the solar system and the universe in general. Astronomical principles and instrumentation. The planets, moons, sun, comets, stars and star formation, galaxies, and cosmology. Course attribute(s): General Education Designation: Natural Sciences (General) – [SG] in combination with AST 102."

c. Detailed evidence of how course meets criterion:

i. Syllabus: Page 1
ii. Reading List: I – XXII, all subsections
iii. Lecture: All lecture topics are covered briefly, but as completely as practical within the time allowed, keeping in spirit with a survey course approach.
iv. Labs:
Lab 1: Scale Model of the Solar System
Lab 2: Celestial Coordinates
Lab 3: Planetarium Exercise
Lab 4: Sundials
Lab 5: Kepler's Laws
Lab 6: The Moon's Landscape
Lab 7: Telescopes and Optics
Lab 8: Astronomy Magazine
Lab 9: Altitude of a Meteor
Lab 10: Sunspots
Lab 11: Stellar Parallax
Lab 12: Galaxy Classification and the Hubble Law
Long Term Lab Project: Sunrise/set Project
Laboratory Final Exam

PART II: At least one of the following additional criteria must be met within the context of the course.

A. Stresses understanding of the nature of basic scientific issues.

a. How course meets spirit:

AST 101 students are continually taught the relevancy of the science of astronomy. Even though some astronomers may study objects millions of light years away, students are reminded that there are many aspects of astronomy that directly affect their lives on an almost daily basis. Examples include: digital imaging technologies developed for astronomical use that have "trickled down" to benefit consumers in the digital camera market, satellite technologies that allow for reliable weather forecasting, an understanding of Venus' greenhouse effect that has implications for the Earth's environment in the context of climate change, an understanding of the Earth's geologic history and humanity's place in it, and many others.

b. Course competencies met:

--Apply the scientific method and other critical thinking models to astronomical phenomena for hypotheses development, experimental design, data acquisition, and data analysis.

--Describe instruments used to detect radiation from the various portions of the electromagnetic spectrum.

--Compare and contrast the physical properties of the planets.

--Explain the probability of extraterrestrial intelligence and the possibility of extraterrestrial communication.

c. Detailed evidence of how course meets criterion:

i. Syllabus: Page 1

ii. Reading List: II.A-D, III.A-G, IV.A-D, V.C, VIII.A-L, XXII.A-H.

iii. Lecture: The Lecture is designed to introduce students to the science of astronomy. Students are challenged to leave aside their preconceptions about astronomy and view the subject with an eye toward the relevancy of the science in our modern world.

iv. Labs:

Lab 1: Scale Model of the Solar System

Lab 4: Sundials

Lab 7: Telescopes and Optics

Long Term Laboratory Project: Sunrise/set Project

B. Develops appreciation of the scope and the reality of limitations in scientific capabilities.

a. How course meets spirit:

As mentioned in part D of section I above, the history of astronomy offers many examples of the limitations in scientific capabilities. Even today, with the most advanced technologies and scientific methods, astronomers must describe their advances in terms of probabilities. Many basic questions about the Universe and our place in it remain unanswered. To name just a few: What is the origin of the Earth's moon? How were galaxies formed in the early Universe? What is the actual process that starts life in the Universe, and how prevalent is it? What is the major constituent of the mass of the Universe (dark matter)? What is the mechanism that is causing the current acceleration of the expansion of the Universe (dark energy)? AST 101 students are presented with these questions and many others. Possible solutions are presented, along with cautionary discussions about the limitations of the methods used to find those solutions.

b. Course competencies met:

-- Outline the history of astronomical thought

--Compare the physical properties of the earth with its moon.
--Describe current cosmological models and their implications on the past and the future
--Explain the probability of extraterrestrial intelligence and the possibility of extraterrestrial communication

c. Detailed evidence of how course meets criterion:
   i. Syllabus: Page 1
   ii. Reading List: I.B, C, G, II.A-D, IV.A-D, VI.A-H, XIX.G, XX.D-F, XXII.A-H
   iii. Lecture: "The Night Sky", "Kepler/Galileo/Newton/The Scientific Method", "The Earth's Moon", "The Milky Way Galaxy", "The Hubble Law", "Cosmology/The Fate of the Universe", "The Early Universe/Extra-Terrestrial Life."
   iv. Labs:
   Lab 1: Scale Model of the Universe
   Lab 2: Celestial Coordinates
   Lab 3: Planetarium Exercise
   Lab 6: The Moon's Landscape
   Lab 11: Stellar Parallax
   Lab 12: Galaxy Classification and the Hubble Law

C. Discusses costs (time, human, financial) and risks of scientific inquiry.

a. How course meets spirit:
The human cost of astronomy is nowhere more evident than in the history of astronomy. Most famously, the tribulations of Galileo point out to students the dangers of discovery in the face of prejudice. Personal danger to astronomers, though, extends much further back in time. The astronomer Aristarchus was persecuted by fanatic Pythagoreans for extolling a heliocentric Universe in the 3rd century, B.C. In modern times, the costs of astronomy are typically more financial. Astronomers pushing the limits of human knowledge require telescopes costing hundreds of millions of dollars, potentially billions if they are to be placed in orbit. Advancement in astronomy can be slow. Kepler spent decades working to discover his laws of planetary motion. Spacecraft equipped to study the outer solar system may take over a decade to reach their goal. AST 101 students come to appreciate the costs inherent in human endeavors that advance our knowledge of the Universe.

b. Course competencies met:
-- Outline the history of astronomical thought.
--Describe instruments used to detect radiation from the various portions of the electromagnetic spectrum.
--Give an overview of the components of the solar system.

--Compare and contrast the physical properties of the planets.

-- Describe current cosmological models and their implications on the past and the future

c. <u>Detailed evidence of how course meets criterion:</u>
   i. Syllabus: Page 1
   ii. Reading List: II.A-D, IV.A-D, VI.H, VIII.K, IX.K, XII.D-F.
   iii. Lecture: "Kepler/Galileo/Newton/The Scientific Method", "The Earth's Moon", "Mars/Jupiter", "Saturn/Uranus/Neptune", "Cosmology."
   iv. Labs:
      Lab 5: Kepler's Laws
      Lab 6: The Moon's Landscape
      Lab 7: Telescopes and Optics
      Lab 12: Galaxy Classification and the Hubble Law
      Long Term Laboratory Project: Sunrise/set Project

Official Course Description: MCCCD Approval: 4-25-1995

AST101 1999 Fall - 9999 LEC 3.0 Credit(s) 3.0 Period(s) 3.0 Load Occ

Survey of Astronomy

Survey of astronomy for the nontechnical student. The history, content, and evolution of the solar system and the universe in general. Astronomical principles and instrumentation. The planets, moons, sun, comets, stars and star formation, galaxies, and cosmology.
Prerequisites: None.

Course Attribute(s):
General Education Designation: Natural Sciences (General) - [SG] in combination with: AST102

Go to Competencies Go to Outline

MCCCD Official Course Competencies:

AST101 1999 Fall - 9999 **Survey of Astronomy**

1. Apply the scientific method and other critical thinking models to astronomical phenomena for hypotheses development, experimental design, data acquisition, and data analysis. (I- XV)
2. Outline the history of astronomical thought. (I)
3. Describe in terms of energy, wavelength, and frequency the various portions of the electromagnetic spectrum. (III)
4. Describe instruments used to detect radiation from the various portions of the electromagnetic spectrum. (II)
5. Compare the physical properties of the earth with its moon. (III, IV)
6. Give an overview of the components of the solar system. (V)
7. Compare and contrast the physical properties of the planets. (VI)
8. Describe the minor components of the solar system. (VII)
9. Describe the physical properties of the sun. (VIII)
10. Explain the significance of the Hertzsprung-Russell diagram. (IX)
11. Describe binary star systems and star clusters. (IX)
12. List the possible steps in the formation of stars. (X)
13. Describe the birth, life, and death of stars. (X)
14. Describe the composition of the interstellar medium and its effects on radiation. (XI)
15. Describe the contents and structure of the Milky Way Galaxy. (XII)
16. Explain the significance of Hubble's Law. (XII)
17. Describe possible models which account for active galaxies. (XIII)
18. Describe current cosmological models and their implications on the past and the future. (XIV)

19. Explain the probability of extraterrestrial intelligence and the possibility of extraterrestrial communication. (XV)

Go to Description Go to top of Competencies

MCCCD Official Course Outline:

AST101 1999 Fall - 9999 **Survey of Astronomy**

- I. History of Astronomical Thought
  - A. Sky at night
  - B. Astronomical scales
  - C. Apparent motions of celestial objects
  - D. Eclipses
  - E. Geocentric universe
  - F. Ancient astronomy
  - G. Scientific method
  - H. Heliocentric universe
  - I. Copernican revolution
  - J. Impact of Galileo, Kepler, and Newton
- II. Instrumentation
  - A. Electromagnetic spectrum
  - B. Spectral line formation and analysis
  - C. Optical telescopes
  - D. Radio telescopes
  - E. Full-spectrum radiation detectors
- III. Earth
  - A. Bulk properties
  - B. Interior structure
  - C. Atmospheric structure
  - D. Magnetosphere
  - E. Earth-moon effects
  - F. Plate tectonics
- IV. Earth's Moon
  - A. Bulk properties
  - B. Orbit and rotation
  - C. Surface features
  - D. Interior
  - E. Origin and history
  - F. Exploration
- V. Overview of the Solar System
  - A. Overall layout
  - B. Terrestrial and Jovian planets
  - C. Planetary configurations
  - D. Interplanetary debris
  - E. Solar system formation models
- VI. The Planets
  - A. Bulk properties
  - B. Orbit and rotation

- C. Surface/atmospheric features
- D. Composition
- E. Internal structure
- F. Magnetic properties
- G. Moons
- H. Rings
- I. Spacecraft exploration

VII. Solar System Debris
- A. Asteroids
- B. Comets
- C. Meteoroids

VIII. Sun
- A. Bulk properties
- B. Interior
- C. Visible surface
- D. Atmosphere
- E. Solar activity

IX. Stars
- A. Distances and motions
- B. Energy production
- C. Magnitudes and luminosity
- D. Temperature and color
- E. Stellar classification
- F. Hertzsprung-Russell diagram
- G. Variable stars
- H. Binary stars and star clusters

X. Stellar Evolution
- A. Steps of stellar formation
- B. Evolution and death of stars
- C. Supernovae
- D. Novae
- E. White dwarfs
- F. Neutron stars
- G. Black holes

XI. Interstellar Medium
- A. Interstellar matter
- B. Nebulae
- C. Interstellar molecules

XII. Galaxies
- A. The Milky Way Galaxy
- B. Galaxy classification
- C. Clusters of galaxies
- D. Distribution of galaxies
- E. Galaxy masses
- F. Hubble's Law

XIII. Active Galaxies
- A. Active galaxies
- B. Radio galaxies
- C. Cores of active galaxies

        D. Quasi-stellar objects
    XIV. Cosmology
        A. Expanding universe
        B. Cosmological models and tests
        C. Cosmic microwave background
    XV. Life in the Universe
        A. Life in the solar system
        B. Prospects for intelligent life in our galaxy
        C. Search for extraterrestrial intelligence

Go to Description   Go to top of Competencies   Go to top of Outline

Official Course Description: MCCCD Approval: 4-25-1995

AST102 1999 Fall - 9999 LAB 1.0 Credit(s) 3.0 Period(s) 2.4 Load Occ

Survey of Astronomy Laboratory

Astronomical observations and exercises designed to familiarize students with the sky, telescopes, and methods used in astronomy.
Prerequisites: None. May accompany AST101.

Course Attribute(s):
General Education Designation: Natural Sciences (General) - [SG] in combination with: AST101

Go to Competencies Go to Outline

MCCCD Official Course Competencies:

AST102 1999 Fall - 9999 **Survey of Astronomy Laboratory**

1. Apply the scientific method and other critical thinking models to astronomical phenomena for hypotheses development, experimental design, data acquisition, and data analysis. (I- XIV)
2. Follow directions in completing laboratory exercises. (II-XIV)
3. Properly and safely use laboratory tools, e.g. calculator, computer, rulers, protractors, cameras, telescopes, magnifiers, maps, etc., for data acquisition, data analysis, or simulation. (II-XIV)
4. Work effectively in collaborative groups. (II-XIV)
5. Write accurate and meaningful reports analyzing experiments, both qualitatively and quantitatively. (II-XIV)

Go to Description Go to top of Competencies

MCCCD Official Course Outline:

AST102 1999 Fall - 9999 **Survey of Astronomy Laboratory**

- I. Scientific Method and Critical Thinking Models
- II. Possible Laboratory Topics
  - A. History of astronomical thought
    1. Sky at night
    2. Kepler's laws of planetary motion
    3. Geocentric model versus the heliocentric model
    4. Solar system dimensions
    5. Celestial coordinate systems
  - B. Instrumentation
    1. Optical telescopes
    2. Resolution

3. Photometry
4. Astrophotography
5. Electromagnetic spectrum
6. Doppler effect
7. Spectroscopy

C. Earth
1. Surface features
2. Earth-moon effects
3. Seasons
4. Astronomical systems of time

D. Earth's moon
1. Orbit and rotation
2. Surface features
3. Telescopic observations
4. Astrophotography

E. The planets
1. Orbit and rotation
2. Surface/atmospheric features
3. Cratering and vulcanism
4. Moons
5. Ring structure
6. Telescopic observations
7. Astrophotography
8. Photometry

F. Solar system debris
1. Asteroids
2. Comets
3. Meteoroids
4. Telescopic observations
5. Astrophotography
6. Photometry

G. Sun
1. Solar activity
2. Telescopic observations
3. Astrophotography

H. Stars
1. Parallax
2. Astrometry
3. Photometry
4. Spectral classification
5. Hertzsprung-Russell (H-R) diagram
6. Binary stars
7. Star clusters
8. Telescopic observations
9. Astrophotography

I. Stellar evolution
1. Evolution and the H-R diagram
2. Supernovae
3. Novae

    4. Stellar remnants
    5. Telescopic observations
    6. Astrophotography
J. Interstellar medium
    1. Nebulae
    2. Telescopic observations
    3. Astrophotography
K. Galaxies
    1. Variable stars as distance indicators
    2. Galaxy classification
    3. Galaxy masses
    4. Galaxy clusters
    5. Hubble's law
    6. Active galaxies
    7. Telescopic observations
    8. Astrophotography
L. Cosmology
    1. Expanding universe
    2. Cosmological models
    3. Cosmic microwave background
M. Life in the universe
    1. Prospects for intelligent life in our galaxy
    2. Search for extraterrestrial intelligence

Go to Description Go to top of Competencies Go to top of Outline

AST 101: Survey of Astronomy Spring 2013

Instructor: Steve Mutz **Office**: NS 128
Website: http://faculty.scottsdalecc.edu/mutz/
Engrade website: http://www.engrade.com
Telephone: 480-423-6122 **E-mail**: steven.mutz@scottsdalecc.edu
Office Hours: MWF, 8:00 a.m. – 9:00 a.m., TuTh 11:00 a.m. – Noon, or by appointment

Text: No text required. Online reading assignments will be made available.

COURSE DESCRIPTION: Survey of astronomy for the nontechnical student. The history, content, and evolution of the solar system and the universe in general. Astronomical principles and instrumentation. The planets, moons, sun, comets, stars and star formation, galaxies, and cosmology.

PREREQUISITES: None

ONLINE QUIZZES:
There will be weekly quizzes DUE BY THE SUNDAY FOLLOWING EACH WEEK. There will be 16 quizzes for the semester, with the lowest grade being dropped. Quizzes will count for a total 15% of your semester grade.

TESTS: There will be three approximately equally spaced in-class tests worth 20% of your grade each and a final exam (comprehensive) worth 25%. Tests usually consist of a section of multiple-choice questions and a section of essay questions.

ATTENDANCE: *You* will be responsible for your attendance for the lectures. If you know you are going to miss a test date, or if you miss a test due to unforeseen circumstances (flat tire, sickness, etc.), you must contact me as soon as possible (that day or prior to it) so that I can arrange a make-up for you.
IF YOU MUST WITHDRAW, YOU ARE RESPONSIBLE FOR ENSURING THE PROPER PAPERWORK IS COMPLETED.

Cellular Phones: Turn them off or on "silent" before you walk into class.

GRADING BREAKDOWN: Course grades will be assigned based on the following:
Tests = 20% each, 60% total
Online Quizzes = 15%
Final Exam = 25%
Grading Cutoffs: A=100 – 85%, B= 84.9 – 75%, C=74.9 – 60%, D=59.9% - 50%

Student Responsibilities and Resources: See the Student Handbook and College Catalogue for a full description.

Final Exam: See the Topic Schedule.

EnGrade: Each student will be emailed a user name and initial password for an Engrade Class Website account. The Engrade website contains several essential tools for this class:

1. A class calendar containing:

a. topic schedule

b. quiz due dates

2. Online quizzing.

3. Wikis with information about the class.

4. Student progress and class grade information.

5. Review sheets for tests.

6. Test answer keys.

The Engrade website can be accessed at www.engrade.com/user/login.php

IMPORTANT: If you do not receive an email from me with your initial login information for the Engrade Class Website, contact me ASAP.

My Faculty Website: My SCC website is located at:
https://faculty.scottsdalecc.edu/mutz/

Due to some of the limitations with the Engrade website, several important items are located on my SCC website:

1. Lecture slides for each topic in Powerpoint format. These are usually identical to those presented in class.

AST 101 Topic Schedule

	Tuesday	**Thursday**
Week 1	Introduction/Metric System	The Night Sky
Week 2	Motions of the Moon/Eclipses/Ancient Astronomy	Ptolemy/Copernicus/Tycho Brahe
Week 3	Kepler/Galileo/Newton/The Scientific Method	Light/EM Radiation
Week 4	Telescopes/Observatories	Spectroscopy/Kirchoff's Laws/The Doppler Effect
Week 5	Test #1	Solar System Overview
Week 6	The Earth	The Earth's Moon/Mercury
Week 7	Mars/Jupiter	Saturn/Uranus/Neptune
Week 8	Pluto and the Dwarf Planets	Solar System Debris: Asteroids, Comets, Meteoroids
Week 9	SPRING BREAK	SPRING BREAK
Week 10	Test #2	The Sun
Week 11	The Nature of the Stars	The H-R Diagram
Week 12	The ISM	Stellar Middle Age
Week 13	The Deaths of Low-Mass Stars/The Deaths of High-Mass Stars	Relativity/Black Holes/Other Stellar Remnants
Week 14	Test #3	The Milky Way Galaxy
Week 15	Galaxies/Hubble Classification	The Hubble Law/Quasars/Active Galaxies
Week 16	Cosmology/The Fate of the Universe	The Early Universe/Extra-Terrestrial Life
Week 17	Final Exam	

http://en.wikibooks.org/wiki/General_Astronomy

I. Early History of Astronomical Thought

A. Sky at night
http://earthsky.org/tonight
http://en.wikipedia.org/wiki/Night_sky

B. Astronomical scales
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/cosmic_reference/distance.html

C. Celestial sphere
http://en.wikipedia.org/wiki/Equatorial_coordinate_system
http://earthsky.org/astronomy-essentials/what-is-the-ecliptic
http://www-istp.gsfc.nasa.gov/stargaze/Scelsph.htm
http://www-istp.gsfc.nasa.gov/stargaze/Secliptc.htm
http://www-istp.gsfc.nasa.gov/stargaze/Sseason.htm

D. Apparent motions of celestial objects
http://www.scienceu.com/observatory/articles/retro/retro.html
http://astro.unl.edu/classaction/animations/renaissance/retrograde.html

E. Eclipses
http://eclipse.gsfc.nasa.gov/eclipse.html

F. Geocentric universe
http://library.thinkquest.org/28327/html/exploration/people/aristotle.html
http://space.about.com/cs/astronomerbios/a/ptolemybio_2.htm

G. Ancient astronomy
http://space.about.com/od/astronomerbiographies/a/aristarchusbio.htm
http://space.about.com/cs/astronomerbios/a/Eratosthenesbio.htm

II. Birth of Modern Astronomy
http://www.physicsoftheuniverse.com/dates.html
http://space.about.com/od/astronomerbiographies/a/copernicusbio.htm
http://hyperphysics.phy-astr.gsu.edu/hbase/kepler.html
http://www.pbs.org/wgbh/nova/galileo/
http://science.howstuffworks.com/innovation/scientific-experiments/scientific-method1.htm

A. Scientific method
B. Heliocentric universe
C. Copernican revolution
D. Impact of Galileo, Kepler, and Newton
E. Solar system dimensions

III. Radiation

http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html
http://www.astronomynotes.com/light/s1.htm
http://hyperphysics.phy-astr.gsu.edu/hbase/mod1.html

A. Evidence of the wave nature of radiation
B. Electric/magnetic field relationships
C. Electromagnetic spectrum
D. Evidence of the particle nature of radiation
E. Radiation laws and the Doppler effect
F. Model of the atom
G. Spectral line formation and analysis

IV. Telescopes

http://en.wikipedia.org/wiki/Reflecting_telescope
http://en.wikipedia.org/wiki/Refracting_telescope
http://www.nrao.edu/index.php/learn/radioastronomy/radiotelescopes
http://hubblesite.org/the_telescope/hubble_essentials/
http://imagine.gsfc.nasa.gov/docs/science/how_l1/xray_telescopes.html
http://imagine.gsfc.nasa.gov/docs/science/know_l1/history1_xray.html

A. Optical telescopes
B. Resolution
C. Radio telescopes and interferometry
D. Full-spectrum radiation detectors

V. Earth

http://solarsystem.nasa.gov/planets/profile.cfm?Object=Earth
http://nineplanets.org/earth.html
http://www.ucmp.berkeley.edu/geology/tectonics.html

A. Bulk properties
B. Hydrosphere
C. Atmosphere
D. Magnetosphere
E. Interior
F. Earth-moon effects
G. Plate tectonics

VI. Earth's Moon

http://nineplanets.org/earth.html
http://solarsystem.nasa.gov/planets/profile.cfm?Object=Moon
A. Bulk properties
B. Orbit and rotation
C. Surface features
D. Cratering and volcanism
E. Surface composition
F. Interior
G. Origin and history
H. Exploration

VII. Overview of the Solar System
http://nineplanets.org/overview.html
http://solarsystem.nasa.gov/planets/index.cfm
A. Overall layout
B. Terrestrial and Jovian planets
C. Planetary configurations
D. Interplanetary debris

VIII. Comparative Planetology: Terrestrial Planets
http://solarsystem.nasa.gov/planets/index.cfm
http://www.nasa.gov/mission_pages/messenger/main/index.html
http://messenger.jhuapl.edu/
http://nineplanets.org/venus.html
http://www2.jpl.nasa.gov/magellan/guide.html
(excellent summary of Venus and its exploration)
http://marsrover.nasa.gov/home/index.html
http://nineplanets.org/mars.html
A. Bulk properties
B. Orbit and rotation
C. Surface features
D. Cratering and volcanism
E. Surface composition
F. Internal structure
G. Atmosphere
H. Temperatures
I. Magnetic properties
J. Moons
K. Spacecraft exploration
L. Possibilities of life

IX. Comparative Planetology: Jovian Planets
http://solarsystem.nasa.gov/planets/index.cfm
http://pds.jpl.nasa.gov/planets/
http://www.pbs.org/wgbh/nova/galileo/
http://saturn.jpl.nasa.gov/index.cfm

http://nineplanets.org/neptune.html
A. Bulk properties
B. Discovery
C. Orbit and rotation
D. Composition
E. Atmospheric features
F. Internal structure
G. Temperatures
H. Magnetic properties
I. Ring structure
J. Moons
K. Spacecraft exploration

X. Pluto and Solar System Debris
http://minorplanetcenter.net/
http://solarsystem.nasa.gov/planets/profile.cfm?Object=Pluto
http://solarsystem.nasa.gov/planets/profile.cfm?Object=Dwarf&Display=Moons
(click on the name of each Dwarf Planet in the upper right)
http://solarsystem.nasa.gov/planets/profile.cfm?Object=Comets&Display=OverviewLong
http://nssdc.gsfc.nasa.gov/planetary/comet.html
http://solarsystem.nasa.gov/planets/profile.cfm?Object=Meteors
A. Discovery of Pluto
B. Bulk properties of Pluto
C. Moon of Pluto
D. Origin of Pluto
E. Asteroids
F. Comets
G. Meteoroids

XI. Formation of the Solar System
http://astronomyonline.org/SolarSystem/SolarSystemFormation.asp
http://www.universetoday.com/15567/formation-of-the-solar-system/
A. Role of modeling
B. Solar system formation models
C. Modeling problems

XII. Sun
http://sohowww.nascom.nasa.gov/
http://nineplanets.org/sol.html
http://en.wikipedia.org/wiki/Nuclear_fusion
http://en.wikipedia.org/wiki/Proton-proton_chain_reaction
http://www.physicsoftheuniverse.com/topics_relativity_emc2.html
A. Bulk properties
B. Interior
C. Visible surface
D. Atmosphere

E. Solar activity
F. Energy production

XIII. Measuring the Stars
http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970415c.html
http://sciencevault.net/ibphysics/astrophysics/stellardistances.htm
http://www.skyandtelescope.com/howto/basics/Stellar_Magnitude_System.html
http://hyperphysics.phy-astr.gsu.edu/hbase/starlog/staspe.html
http://en.wikipedia.org/wiki/Stellar_classification
http://en.wikipedia.org/wiki/Hertzsprung%E2%80%93Russell_diagram
A. Distances
B. Motions
C. Magnitudes and luminosity
D. Temperature and color
E. Spectral classification
F. Hertzsprung-Russell (H-R) diagram

XIV. Binary Stars and Star Clusters
http://hyperphysics.phy-astr.gsu.edu/hbase/starlog/bistar.html
http://hyperphysics.phy-astr.gsu.edu/hbase/starlog/bispect.html#c1
http://apod.nasa.gov/apod/ap970219.html
http://apod.nasa.gov/apod/ap050830.html
http://messier.seds.org/open.html
http://en.wikipedia.org/wiki/Open_cluster
http://ned.ipac.caltech.edu/level5/ESSAYS/Cudworth/cudworth.htmlhttp://www.scientificamerican.com/article.cfm?id=how-do-scientists-determi
http://astronomyonline.org/Stars/OpenClusters.asp?Cate=Home&SubCate=OG03&SubCate2=OG0301
http://astronomyonline.org/Stars/GlobularClusters.asp?Cate=Home&SubCate=OG03&SubCate2=OG0302
A. Binary star classifications
B. Stellar sizes and masses
C. Open star clusters
D. Globular star clusters
E. H-R diagrams of clusters
F. Cluster distances and locations
G. Cluster ages

XV. Interstellar medium
http://en.wikipedia.org/wiki/Timeline_of_knowledge_about_the_interstellar_and_intergalactic_medium
http://www-ssg.sr.unh.edu/ism/index.html (an in-depth tutorial about the ISM)

A. Interstellar matter
B. Emission nebulae
C. Dark nebulae
D. 21-centimeter radiation
E. Interstellar molecules

XVI. Star Formation

http://www-ssg.sr.unh.edu/ism/index.html
A. Gravitational forces vs thermal pressure
B. Steps of stellar formation
C. Low-mass formation
D. High-mass formation
E. Evidence of stellar formation
F. HII regions and star clusters

XVII. Stellar Evolution

http://www.astro.uni-bonn.de/~javahrd/v071/index.html
http://www.youtube.com/watch?v=8XFL7kS41YM
http://www.youtube.com/watch?v=xJ8E2BeB5ow (low mass stars)
http://www.youtube.com/watch?v=FWuV7dtFBTw (high mass stars)
http://imagine.gsfc.nasa.gov/docs/science/know_l2/supernovae.html
http://en.wikipedia.org/wiki/Nova
A. Evolution and the H-R diagram
B. Evolution and death of low-mass stars
C. Evolution and death of high-mass stars
D. Supernovae
E. Formation of the elements
F. Cycle of stellar evolution
G. Evidence of stellar evolution
H. Binary star system evolution
I. Novae

XVIII. Stellar Remnants

http://imagine.gsfc.nasa.gov/docs/science/know_l1/dwarfs.html
http://imagine.gsfc.nasa.gov/docs/science/know_l2/dwarfs.html
http://imagine.gsfc.nasa.gov/docs/science/know_l1/neutron_stars.html
http://imagine.gsfc.nasa.gov/docs/science/know_l1/pulsars.html
http://imagine.gsfc.nasa.gov/docs/ask_astro/neutron_star.html
http://library.thinkquest.org/27930/relativity.htm
http://www.physicsoftheuniverse.com/topics_relativity_emc2.html
http://www.physicsoftheuniverse.com/topics_relativity_light.html
http://www.physicsoftheuniverse.com/topics_relativity_special.html
http://www.physicsoftheuniverse.com/topics_relativity_gravity.html
http://www.physicsoftheuniverse.com/topics_blackholes.html
http://science.howstuffworks.com/science-vs-myth/everyday-myths/relativity.htm

http://astronomyonline.org/Stars/BlackHole.asp?Cate=Stars&SubCate=OG04&SubCate2=OG0405
http://imagine.gsfc.nasa.gov/docs/ask_astro/snr.html

A. White dwarfs
B. Neutron stars
C. Black holes
D. Evidence for stellar remnants

XIX. Milky Way Galaxy

http://ned.ipac.caltech.edu/level5/ESSAYS/Carlberg/carlberg.html
http://www.windows2universe.org/kids_space/milky_way_ask.html
http://cosmology.carnegiescience.edu/timeline/1920
http://www.aip.org/history/cosmology/ideas/island.htm
http://www.astro.caltech.edu/~george/ay20/eaa-darkmatter-obs.pdf
http://en.wikipedia.org/wiki/Dark_matter
http://ns.umich.edu/new/releases/7892-black-hole-at-milky-way-core-powers-galaxys-fastest-stars
http://www.youtube.com/watch?v=fytriKJ8xhE

A. Bulk properties
B. Spiral nebulae vs island universes
C. Variable star classifications
D. Variable stars as distance indicators
E. Stellar distributions in the Milky Way
F. Radio studies of the Milky Way
G. Mass of the Milky Way
H. Galaxy core activity

XX. Normal Galaxies

http://ned.ipac.caltech.edu/level5/ESSAYS/Evans/evans.html (Cepheid Variables)
http://hubblesite.org/reference_desk/faq/answer.php.id=40&cat=galaxies
http://en.wikipedia.org/wiki/Hubble_sequence
http://ned.ipac.caltech.edu/level5/ESSAYS/Elmgreen/elmgreen.html (Spiral galaxies)
http://ned.ipac.caltech.edu/level5/ESSAYS/Baum/baum.html (Elliptical galaxies)
http://ned.ipac.caltech.edu/level5/ESSAYS/Dressler/dressler.html (Galaxy evolution)

A. Galaxy classification
B. Clusters of galaxies
C. Distribution of galaxies
D. Galaxy masses
E. Hubble's law
F. Galaxy formation and evolution

XXI. Active Galaxies

http://ned.ipac.caltech.edu/level5/ESSAYS/Blandford/blandford.html
(Quasars)
http://imagine.gsfc.nasa.gov/docs/science/know_l1/active_galaxies.html
http://imagine.gsfc.nasa.gov/docs/ask_astro/quasar.html

A. Distant galaxies
B. Active galaxies
C. Radio galaxies
D. Cores of active galaxies
E. Quasi-stellar objects
F. Evolution of active galaxies

XXII. Cosmology

http://ned.ipac.caltech.edu/level5/ESSAYS/Clayton/clayton.html (The age of the Universe)
http://ned.ipac.caltech.edu/level5/ESSAYS/Bothun/bothun.html (Protogalaxies)
http://ned.ipac.caltech.edu/level5/ESSAYS/Barrow/barrow.html (Cosmology)
http://www.physicsoftheuniverse.com/topics_bigbang.html (TAKE A GOOD LOOK AT ALL OF THE LINKS IN THE TOPIC INDEX)
http://www.universetoday.com/79777/cosmic-background-radiation/
http://en.wikipedia.org/wiki/Ultimate_fate_of_the_universe
http://map.gsfc.nasa.gov/
http://www.pbs.org/wgbh/aso/databank/entries/dp65co.html
http://www.pbs.org/wgbh/nova/space/history-universe.html (an interactive timeline of the Universe)
http://en.wikipedia.org/wiki/Chronology_of_the_universe#Very_early_universe

A. Large scale structure
B. Homogeneity and isotropy
C. Expanding universe
D. Cosmological models
E. Cosmological tests
F. Cosmic microwave background
G. Primordial nucleosynthesis
H. Formation of large scale structure

AST 102: Survey of Astronomy Lab Spring 2013

Instructor: Steve Mutz **Office**: NS 128
Website: http://faculty.scottsdalecc.edu/mutz/
Engrade website: http://www.engrade.com
Telephone: 480-423-6122 **E-mail**: steven.mutz@scottsdalecc.edu
Office Hours: MWF, 8:00 a.m. – 9:00 a.m., TuTh 11:00 a.m. – Noon, or by appointment

Text: There is no lab manual for the class, I will provide lab materials as needed.

PREREQUISITES: None (However, taking AST 101 concurrently or previously is strongly recommended.)

ATTENDANCE: You are expected to attend each lab session, and to complete the exercise and turn it in each time prior to leaving. Therefore, I take attendance based on you turning in your labs. If you must miss a lab, let me know ahead of time and we will try to make some other arrangements. Labs missed due to unforeseen circumstances will be dealt with on an individual basis. In any case, call me! You will be allowed one make-up lab during the course of the semester (see below).

BEFORE EACH CLASS: You will be given the lab assignments ahead of time and will know which labs are scheduled when (except for schedule changes due to weather). Therefore, you will be expected to review each week's lab prior to class. Be ready to discuss each day's lab and to ask questions at the beginning of each class.

WHAT TO BRING TO CLASS: In addition to your lab manual or handout, bring your calculator, pencil, pen, eraser, and a ruler.

DUE DATES: All labs (unless noted) are to be completed and handed in before you leave for that night. Late work will NOT be accepted and make-ups are few and far between! (see MAKE-UPS, below)

BAD WEATHER: If the weather will not cooperate for an outdoor lab, be ready to do the next scheduled indoor lab.

PLAGIARISM VERSUS TEAMWORK: All labs MUST be completed on the handouts given. Working with colleagues is always encouraged, but this is not the same as copying their work. Not only is that plagiarism, which is outlawed by every school in the known world and subject to stiff penalties, but you are then at the mercy of THEIR mistakes and you will sink (or swim) together. If this is unclear, come see me.

LONG TERM PROJECT: The long term project, (The Sunrise/Sunset Project), will be handed out later and discussed in detail. It will be worth 3 labs and will be turned in near the end of the semester. More on this later.

TESTS: There will be a comprehensive, open-notes, open-lab final exam on the last day of class. This test will be worth 25% of your grade. NO MAKE-UP FINAL EXAM WILL BE GIVEN!

EXTRA CREDIT & MAKE-UP LABS: There will be one make-up lab scheduled for the class prior to the final exam. If you perform all of the scheduled labs, you may not do the make-up lab. If you miss a lab, then you may do the make-up lab.

NOTE: Assignments and scheduled events are tentative and may have to be changed at a later date due to weather and other unforeseen circumstances.

Grading Cutoffs: A=100 – 90%, B= 89.9 – 80%, C=79.9 – 70%, D=69.9% - 60

Final Exam: See the Lab Schedule.

<u>Tentative AST 102 Lab Schedule</u>

<u>Week 1</u>
Scale Model of the Solar System

<u>Week 2</u>
Celestial Coordinates

<u>Week 3</u>
Planetarium Exercise

<u>Week 4</u>
Sundials
Start Sunrise/set Project

<u>Week 5</u>
Kepler's Laws

<u>Week 6</u>
The Moon's Landscape

<u>Week 7</u>
Telescopes and Optics

<u>Week 8</u>
Astronomy Magazine

<u>Week 9</u>
Spring Break - NO SCHOOL

<u>Week 10</u>
Determining the Altitude of a Meteor

<u>Week 11</u>
Sunspots Pt. I

<u>Week 12</u>
Sunspots Pt. II

Week 13

Stellar Parallax

Week 14

Galaxy Classification and the Hubble Law

Week 15

Make-up lab/Turn in sunrise/set project

Week 16

Lab final exam

Name________________________________

A Model of the Solar System

I. Introduction

Astronomers typically encounter distances and sizes which are incomprehensibly large. The size of our galaxy (an average-sized one) is so large that light takes 80,000 years to cross it. In our own solar system, the distance from the Earth to the Sun is 150 million kilometers. Traveling at 55 mph for 24 hours a day, it would take you 190 years to drive this distance in your car! To gain an appreciation for the scale of the universe and even our own solar system requires us to reduce them to something a little more manageable. One way to do this is to construct a scale model of the objects involved. This lab will familiarize you with the relative distances and sizes of the planets in our solar system by making such a model.

Remember to show your work for all calculations!!

II. The Sizes of the Planets

The following table lists the radii of the nine planets in our solar system and the Sun in kilometers (Remember: 1 kilometer = 1,000 meters = 0.621 miles). We want to create a scale for our model of the Solar system which will be small enough to be manageable, yet large enough so that the planets don't become microscopic! Convert the planetary radii to centimeters in Table 1 and then reduce those sizes by a factor of 10^{10}. Remember that 1 meter = 100 centimeters.

Show your work COMPLETELY for your calculations for one of the planets in the space below Table #1.

Table 1. Planetary Sizes

Column #1 Object	Column #2 Radius (km)	Column #3 Radius in Scientific Notation	Column #4 Radius (cm)	Column #5 Scaled Radius (column 4 divided by 10^{10})
Sun	696,000			
Mercury	2,439			
Venus	6,051			
Earth	6,378			
Mars	3,397			
Jupiter	71,492			
Saturn	60,268			
Uranus	25,559			
Neptune	24,764			

In the space below, construct scaled drawings of the Sun and planets using the scaled radii in column #5 in centimeters. Be sure to label the drawings.

III. The Distances Between the Planets

Table 2 lists the distances of the nine planets in our solar system from the Sun in kilometers. Convert the planetary distances to meters and then reduce those distances by a factor of 10^{10}.

Show your work COMPLETELY for your calculations for one of the planets in the space below Table #2.

Table 2. Planetary Distances from theSun

Column #1 Object	Column #2 Distance from the Sun (km)	Column #3 Distance from the Sun (m)	Column #4 Scaled Distance (column 3 divided by10^{10})
Mercury	$5.79 x 10^7$		
Venus	$1.08 x 10^8$		
Earth	$1.50 x 10^8$		
Mars	$2.28 x 10^8$		
Jupiter	$7.78 x 10^8$		
Saturn	$1.43 x 10^9$		
Uranus	$2.87 x 10^9$		
Neptune	$4.50 x 10^9$		

IV. Astronomical Distance Units for the Solar System

Even in the relatively small neighborhood of our solar system, the distances become large very quickly. Using units such as kilometers becomes unwieldy when they reach the billions and beyond. Astronomers have therefore created their own unit for measuring distances within the solar system. They have adopted the distance between the Earth and the Sun for the solar system yardstick. This distance, 150 million kilometers (see table 2, above), is given the name "Astronomical Unit," abbreviated as AU. The distance from the Earth to the Sun (or the Sun to the Earth) is then 1 astronomical unit, or 1 AU. Convert the distances in Table 2 to astronomical units and enter the data in Table 3 below.

Show your work COMPLETELY for your calculations for one of the planets in the space below Table #3.

Table 3. Planetary Distances (AU's)

Column #1 Object	Column #2 Distance from Sun (km)	Column #3 Distance from Sun (AU)
Mercury	$5.79x10^7$	
Venus	$1.08x10^8$	
Earth	$1.50x10^8$	
Mars	$2.28x10^8$	
Jupiter	$7.78x10^8$	
Saturn	$1.43x10^9$	
Uranus	$2.87x10^9$	
Neptune	$4.50x10^9$	

V. Questions

1. Which planet most closely resembles the Earth in size?

2. Which planet is the largest? How many times larger than the Earth is it?
   Which planet is the smallest? How many times smaller than the Earth is it? SHOW YOUR WORK!!
   (The Sun is NOT a planet!)

3. How many Earths would fit inside the Sun? (Hint: volume = $(4/3)\pi r^3$ where r = radius and π=3.1415926)

4. How many times farther from the Sun is Jupiter than the Earth? How many times farther from the Sun is Neptune than the Earth?

Name ______________________

Celestial Coordinates

I. Introduction

Astronomers need a coordinate system for the sky just as navigators and geographers require a coordinates system for the surface of the Earth. Such a system ensures that different parties can refer to the same point in the sky without having to resort to such directions as "in the constellation Canis Majoris" or "low in the western sky," that are ambiguous at best.

Astronomers have borrowed the Earth's geographical coordinate system of latitude and longitude, in a modified form. We imagine the universe as a transparent sphere centered on the Earth with the planets, Sun, and stars arranged on the surface of the sphere. This arrangement is purely an artificial construct based on how the sky appears to an Earth-based observer, not how it actually is. Coordinates on this **Celestial Sphere** have coordinates analogous to the latitude and longitude coordinates used for the Earth's surface. The **Celestial Equator** is the projection of the Earth's equator onto the celestial sphere. The **Celestial North/South Pole** is the projection of the Earth's North/South pole onto the celestial sphere. **Declination** is the celestial equivalent of latitude, measured in degrees, + for north of the celestial equator, - for south of the celestial equator. **Right Ascension** is the celestial equivalent of longitude, measured in hours, increasing eastward. There are 24 hours of right ascension in a full circuit of the celestial sphere.

In this lab, you will familiarize yourself with the celestial coordinate system of right ascension and declination (RA and DEC), as well as how these coordinates allow astronomers to determine some fundamental observational data.

II. Right Ascension and Declination

A. Determine the Right Ascension and Declination of several objects:

1. Start up the **Starry Night** program on one of the computers by double-clicking on its icon on the computer.

2. In the upper left hand **Time and Date** banner, ensure that the time and date are correct for today.

3. Ensure that the **Viewing Location** in the center banner is set to "Phoenix, United States."

4. Under the **Options** control at the top of the screen, select **Other Options…**, then **Local Horizon.** Select **Flat Horizon**, then **Translucent**, then click **OK**.

5. Under the **View** control at the top, select **Celestial Guides**, then select **Grid** and **Celestial Poles**.

6. Under **View**, select **Constellations**, then **Boundaries**, **Labels,** and **Astronomical**.

7. Under the **View** control, select **Hide Daylight**.

III. Motions of Celestial Objects

1. Under the **Gaze** banner at the top right, click **"N"** to point North, and move the field of view until the **ALT** (altitude) value is 30 degrees. Change the **Time Flow Rate** to **"300X.**"

In what direction does the sky appear to rotate as time moves forward?

____

2. Now click **"S"** in the **Gaze** banner to look due south. Repeat step 1. Now how do the stars appear to move?

____

3. Now move your viewing area until you are looking due west, and change the **ALT** to 15 degrees. Reset **TIME** to the current time of day. Advance the time until the sun sets to determine sunset for today:

time of sunset for today = __________________ .

Do the same for sunrise today on the eastern horizon:

time of sunrise = __________________ .

At what angle do objects rise and set with respect to the horizon?

4. Determine the Right Ascension and Declination of the objects listed in the following table. Under **Edit**, select **Find...,** then either type in the name of the object in the search box or select it from the list already displayed. Click on the triangle to the left of the object's name and select **Centre.** Placing the cursor on an object will display its name and information about that object. Also list the constellations in which the objects are found and their distances.

	Right Ascension	Declination	Constellation	Distance from Earth
Jupiter				
Sun				
Sirius				
Procyon				
Betelgeuse				
Rigel				
Polaris				

5. Now locate and center on the Moon.

What is the phase of the Moon today?

What constellation is it in today?

What are the times of moonrise and moonset for today?

IV. The Ecliptic

The ecliptic is the apparent path of the Sun with respect to the stars over the course of a year. Since this motion is caused by the Earth revolving around the Sun, it also is the plane of the Earth's orbit and by convention the plane of the Solar System.

1. Under **View** select **Ecliptic Guides**, then **Ecliptic**, then **Celestial Guides**, then de-select **Grid** and select **Equator**.

What is the angle between the ecliptic and the celestial equator?

_________ degrees

On what date(s) this year is the Sun on both the celestial equator and the ecliptic? (Declination = 0^{o}).
Helpful user tip: You can change dates by clicking on either the **Month** or **Day** in the **Time and Date** banner, then using the mouse scroll wheel to change the value

On what date(s) this year is the Sun the farthest north of the celestial equator? (Declination is greatest + number)

On what date(s) this year is the Sun the farthest south of the celestial equator? (Declination is greatest - number)

The Nighttime Sky Planetarium Exercise

Introduction
The human perception of the nighttime sky is that of looking at the inside of a hemisphere with all celestial objects arranged two-dimensionally on it. We now know that the Universe is indeed three-dimensional, but that perception of a Celestial Sphere lends itself well to a coordinate system for the sky similar to latitude and longitude. It also makes the planetarium ideal for accurately simulating the night sky.

I. The Constellations and Stars

1. While in the planetarium, determine which of the following constellations would be visible tonight from Scottsdale, and where in the sky they would be in general terms:

a. Ursa Major

b. Orion

c. Gemini

d. Cassiopeia

e. Taurus

2. What planets are visible tonight in the evening sky? What feature on the Celestial Sphere are they always close to?

3. In what direction do the stars and planets move during the course of the night?

4. Where is the star Polaris in the sky? What is special about its place in the sky?

5. What is the phase of the Moon tonight?

6. Where would you be on the Earth to see the stars set, and rise, perpendicular to the horizon?

II. Celestial Coordinates

Astronomers use the coordinate system of Right Ascension and Declination for the Celestial Sphere, similar to Longitude and Latitude for the Earth' surface

1. What is the Declination of Polaris? Is it the same for everyone on Earth?

2. Through what feature in the constellation Orion does the Celestial Equator pass?

3. Where would the Celestial Equator be in the sky if you were standing at the Earth's Equator? If you were standing at the Earth's North Pole?

4. Where would Polaris be in the sky if you were standing at the Earth's Equator? If you were standing at the Earth's North Pole?

5. Where is the Celestial Equator relative to the Ecliptic?

III. The Nighttime sky

1. What does the Milky Way look like from Earth?

2. In what direction does the Sun appear to move *with respect to the stars* during the course of the year? What is the apparent path the Sun takes called?

IV. Questions

1. How can you determine your latitude while in the Northern Hemisphere?

2. Why do we always see the planets close to the Ecliptic (but not always exactly on it)?

3. Explain why the Milky Way looks the way it does from the Earth. In other words, how are the Earth and Milky Way located so as to give us this view of it?

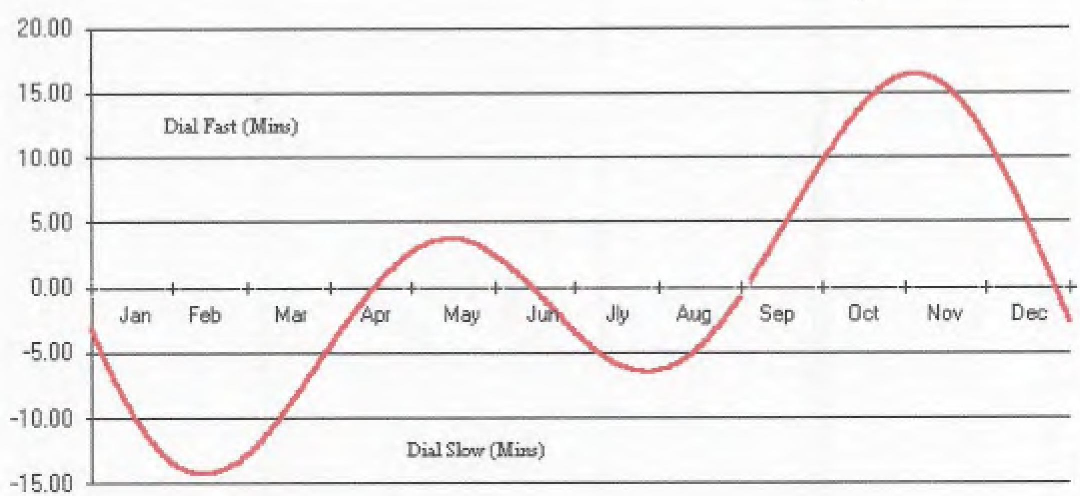
Name ______________________

Making a Sundial

I. Introduction

Using the Sun to tell time is an old idea which has been used for thousands of years. There are examples of "shadow clocks" which were found in tombs of the Egyptian Pharaohs. A sundial makes use of the fact that the sun appears to travel across the sky at a rate of 360 degrees every 24 hours. They come in many different styles and designs. The most common are the **horizontal** and **equatorial** sundials. In this lab you will construct an equatorial sundial.

Sundials tell "sun time" which is based on the idea that when the sun reaches its highest point in the sky, it is **noon**. However, the time interval between noon on one day and noon on the next day is sometimes less than and sometimes more than 24 hours. This is a combination of two separate causes: the Earth is sometimes closer to the Sun and sometimes farther away since its orbit is not perfectly circular. The Sun appears to move fastest across the sky when the Earth is closest. Also, the ecliptic is not in the same plane as the Celestial Equator. That means that the Sun moves at different angles to the Celestial Equator at different times of the year. At the Solstices, the Sun moves parallel to the Celestial Equator and therefore changes its position relative to the stars the fastest. The combination of these two effects as a function of the time of year is summarized by the following chart, called **the Equation of Time**:



II. Making an Equatorial Sundial

1. Draw a line across the top of the cardstock included with this lab 1 cm from the top. Do the same 1 cm from the bottom.

2. Mark the center of the top line as point "O" and the center of the bottom line as "P."

3. Draw a line connecting points O and P. This is line OP.

4. Place a protractor with its center at on point O and draw a curve all the way around the outside of the protractor.

5. Make a pin hole through point O and turn the cardstock over. Again draw around a protractor centered on point O so that the two drawings of the protractor are on top of each other.

6. On one side mark off 15° intervals on the curved portion of the protractor tracings and number these **hour lines** from 6 a.m. at the top right to 6 p.m. at the top left, numbering clockwise.

7. Draw a line on the cardstock 9 cm below the top line and fold along this line so that the hour markings from step #6 face **outward**.

8. Push a thin rod through the cardstock at point O and secure its bottom at point P, so that there is 14.4 cm of the rod between points O and P. Make sure the rod is perpendicular to the face of the cardstock with the hour markings. By doing this, the rod is parallel to the axis of the Earth's rotation and points to the North Celestial Pole when properly positioned.

Your sundial is now completed! The rod forms what is called the sundial's **gnomon**. The location of the gnomon's shadow will indicate the time of day.

III. Using your sundial to tell time

1. Take your sundial outside and position it with the gnomon pointing in the direction of true north. To find true north, use a magnetic compass to find magnetic north. In Scottsdale, true north is 13° counter-clockwise from magnetic north.

2. Note the time of day by a time piece such as a watch. What is the time displayed by the sundial?

Sundial time ___________ Timepiece time __________

Equation of Time Correction from 1st page __________

Time difference (sundial – timepiece - Equation of Time) = ___________ minutes

IV. Questions

1. Toward what feature on the Celestial Sphere does the gnomon point?

2. What do you think will happen to the length of the gnomon's shadow as the day goes on?

3. Describe a method for constructing a horizontal sundial (surface with the hour markings horizontal). Specifically, how would you place the gnomon? What would the spacing for the hour marks look like? THINK CAREFULLY!! (Hint: Think about the horizontal shadow of your gnomon)

4. What other effect leads to a difference between clock and sundial time? Hint: Where is the Sun in the sky here in Phoenix compared to, say, El Paso, Texas at the same (clock) time of day?

5. How would you make a "stardial?" That is, a timepiece for telling time with the stars.

Name________________________

Sunrise/Sunset Long -Term Project

(75 points)

I. Introduction

There are many events and motions in the sky which are not immediately apparent from a cursory glance. Long term observations reveal a lot about the motions of the planets (including the Earth), the Moon, and the Sun. This project will allow you to make long-term observations of the Sun and explain your observations based on a knowledge of basic modern Astronomy.

II. The Observations

1. Pick a location from which you can consistently observe either sunsets or sunrises for a long period of time (5-6 weeks). Note: You MUST make ALL of your observations from exactly the same location!! Also, choose a place that has a relatively flat horizon in the direction of sunrise/sunset that won't change. If you observe sunsets standing east of a multi-story building under construction, you will get inconsistent results.

2. Decide whether you will observe sunsets or sunrises for this project. You cannot switch in the middle of the lab. It must be one or the other. Remember, you will be doing this periodically for about six weeks.

3. During your first observation, make a careful sketch of the horizon in the direction of sunrise/sunset. Be sure to include landmarks and objects that will help you to locate the exact location of the sunrise/sunset on your horizon. Update this sketch with every subsequent observation, or make a new sketch. For sunsets, mark due West on your sketch. For sunrises, mark due East on your sketch.

Possible option: photographs of the sunset/sunrise show this very neatly.

4. Record the exact time, date, and location of sunrise/sunset every 3 to 4 days (this can be changed slightly to allow for bad weather) for 6 weeks. Sunset is defined as the moment when the last portion of the Sun moves below the horizon. Sunrise is defined as the moment when the first portion of the Sun moves above the horizon.

Use the techniques from the *Altitude and Azimuth* lab to measure the Azimuth the sun rises, or the Azimuth the sun sets. Use the data table on the next page to record the information from your observations.

5. Answer the questions following the data table. Referencing a basic astronomy text may be helpful.

Be sure to include your sketches or photographs when you turn in your project. (10 points)

III. Data Tables (15 points)

Observations of ______________________ (Choose sunrise or sunset)

Observation #__________ Date__________________ Time of Sunrise/set_______ Azimuth of Sunrise/set______	Observation #__________ Date__________________ Time of Sunrise/set_______ Azimuth of Sunrise/set _____	Observation #__________ Date__________________ Time of Sunrise/set_______ Azimuth of Sunrise/set _____
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Observation #__________ Date__________________ Time of Sunrise/set_______ Azimuth of Sunrise/set _____	Observation #__________ Date__________________ Time of Sunrise/set_______ Azimuth of Sunrise/set _____	Observation #__________ Date__________________ Time of Sunrise/set_______ Azimuth of Sunrise/set _____

IV. Questions

1. What did you notice about the times of Sunrise/sunset during the project? (5points)

2. What did you notice about the locations of Sunrise/sunset? (5 points)

3. Compare your times of sunset/sunrise to those in a local newspaper or astronomical website for your observation dates. Were they the same? Discuss why there can be differences between your observations and the paper's times. (10 points)

4. Explain in detail the physical reasons for your answers to questions #1 & #2. Include at least one sketch of the Earth-Sun system as viewed from space in your discussion. (20 points)

5. If your observations were done 6 months from now, explain how they would have been different. (5 points)

6. If you had made your observations on a planet with an axial tilt of 0^o how would your observations have been different? (5 points)

Name ______________________

Kepler's Laws and the Planets

I. Introduction

Kepler's three laws of Planetary motion are the cornerstones for understanding our solar system. Using Tycho Brahe's observational data and working through trial and error, Kepler was able to discover the true nature of planetary motion and its differences from the Copernican idea of perfect circular motion at constant velocity. Kepler's three laws are usually stated thus:

I. Planetary orbits are ellipses with the Sun at one focus.

II. A planet in orbit about the Sun sweeps out equal areas in equal time intervals.

III. The square of a planet's sidereal period is proportional to the cube of its orbit's semi-major axis. That is: $P^2 = a^3$ where P is the planet's sidereal period in years and a is the semi-major axis of the planet's orbit measured in astronomical units.

In this lab you will use the *Starry Night* computer program to validate and explore the application of Kepler's laws.

II. Kepler's First Law

1. Start up the **Starry Night** planetarium program on one of the computers in the lab room.

2. Under the **Viewing Location** banner, select **Other...**, then **View from:**, then **Stationary Location.**."

3. Select **Cartesian Coordinates** of **x** = 0.0, **y** = 0.0, and **z** = 2.0 au. Set **Theta** = 90 degrees. The Sun will be in the center of the screen and you will have a view face-on to the orbits of the planets.

4. Set the **Zoom** upper right banner to approximately 70° x 36 ° by clicking on the "-" or "+" buttons. Under the **Labels** control, select **Planets**. Under the **Edit** control, select **Find...** and select the Sun. Click on the triangle to the left of the Sun label and select

Centre to center the field of view on the Sun. Hold down the "CTRL" key and click the cursor on the planet Mercury, then select **Orbit** to display the orbit of Mercury on the screen.

5. In the **Time Flow Rate** banner, select a time step of 2 hours.

6. CTRL + Click on the symbol for the planet Mercury to display a list of information about the planet and where it is at that time. Determine the **eccentricity** of Mercury's orbit by doing the following:

a. Determine the closest distance of Mercury to the Sun and the farthest in AU's. The average of these two distances is the **semi-major** axis, *a*, of its orbit.

Mercury's closest distance to Sun (*perihelion*) = _____________

Farthest (*aphelion*) = __________

a = _____________

b. Determine where the center of Mercury's orbit is and how far the Sun is from the center in AU by subtracting its *perihelion* from *a*. This is equal to what is called *c*.
SHOW YOUR WORK!!!

distance of the Sun from center of Mercury's orbit = *c* = ____________ AU.

c. Compute the eccentricity of Mercury's orbit, $e = c/a$:

eccentricity of Mercury's orbit = *e* = ____________________

7. CTRL + click on Mercury and de-select **Orbit** for Mercury.

III. Kepler's Second Law

1. In the **Viewing Location** banner, click on the triangle and then click on **Other....** Select **View from Stationary Location** with **x** = 0, **y** = 0, **z** = 75 au and Theta = 90°.
2. Under **Edit**, select **Find...** then enter "Halley." Click on the left hand triangle next to the entry for "Halley" and select **Centre** and **Orbit.**
3. Under the **Edit** control, select comet Halley's **Info** then **Position in Space.** .
4. Record the **Heliocentric X, Y, and Z** in Table I, below. These will be the X_1, Y_1, and Z_1 for Area 1.
5. Advance the time by 6 years in the **Time and Date** banner and again record the **Heliocentric X, Y, and Z** in Table I, below as the X_2, Y_2, and Z_2 for Area 1.
6. Compute Area 1 by using the following formulas:

$$a = \sqrt{X_1^2 + Y_1^2 + Z_1^2} \quad b = \sqrt{X_2^2 + Y_2^2 + Z_2^2} \quad c = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2}$$

$$s = \frac{a + b + c}{2}$$

$$Area1 = \sqrt{s(s-a)(s-b)(s-c)}$$

7. Choose another 6 year time interval for Comet Halley and repeat steps 3-6 to compute Area 2.
8. CTRL+click on Comet Halley and de-select **orbit.**

Table I. Kepler's 2nd Law for Comet Halley

	X_1	Y_1	Z_1	X_2	Y_2	Z_2	a	b	c	s	Area
Area 1											
Area 2											

IV. Kepler's Third Law

Determine the mass of the planet Jupiter Using Kepler's Third Law by doing the following:

1. Under **Edit** select **Center on ...** and enter "Jupiter.".
2. Under the **Viewing Location** banner, select **Other...**, then **View From...**, **Position Hovering Over,** and **Jupiter.** Select **Set Location.**
3. Click on the triangle in the **Viewing Location** banner then select **Radius X8** and **Hover as Jupiter Rotates.**
4. In the **Time Flow Rate** banner select "1X" and in the **Zoom** Banner, select "120°.
5. Click on the up arrow under the **Viewing Location** banner until the distance from Jupiter reads "0.007 au."
6. For each Galilean moon: Io, Europa, Ganymede, and Callisto, CTRL+click on it, then select **Show Info.** Record the "Orbit Size" and "Length of Sidereal Day" and record in Table II, below.

Table II. Kepler's 3rd Law for Jupiter

Moon	P(days)	P (years)	*a* (km)	*a* (AU)	P^2	a^3
Io						
Europa						
Ganymede						
Callisto						

2. Compute the Mass of Jupiter from each Galilean moon, in Solar Masses, by using the following form of Kepler's Third Law:

   $M_J + M_2 = a^3/P^2$

   Where M_J is the Mass of Jupiter in Solar Masses and M_2 is the Mass of a Galilean moon in Solar Masses. Assume the mass of each moon is negligible compared to that of Jupiter.

   Use 1 AU = 1.5×10^8 km and 1 year = 365.26 days.

   SHOW YOUR WORK BELOW.

Average of M_J = ______________________

Your answer is in units of Solar Masses. If the Earth has a mass of 3.005×10^{-6} Solar Masses, how many times more massive than the Earth is Jupiter?

V. Questions

1. Based on your results in Table I, comment on the validity of Kepler's second law for comet Halley. If you didn't get equal areas in equal time intervals, what do you think caused the discrepancy? What did you notice about the speed of the comet in its orbit?

2. In 1996, comet Hyakutake passed relatively close to the Earth and was a brilliant sight in the evening spring sky. Its orbital period around the Sun is about 114,000 years. What is its orbit's semi-major axis?

Name ________________________

The Moon's Landscape

I. Introduction

The Moon is a world unto itself with many of the same features as the Earth. It has mountain ranges, isolated peaks, craters, plains, and clefts are only a few. Each time you study the Moon, you will see new features.

In this lab, you will use a detailed map of the Moon to explore some of these features. This lab will also prepare you for later telescopic study of the Moon.

The Moon map provided to you has several features to note:

a. Locations are in Latitude and Longitude, as on the Earth.
b. North, south, east, and west are as on the Earth.
c. The back of the map has an index of features.
d. The key at the lower left corner tells the elevations of the features. Look at it carefully!
e. A small map at the lower right corner emphasizes the Maria, or plains.

II. Study of Lunar Features

A. Craters vary in size from microscopic to hundreds of miles in diameter. Some are brilliantly white to a dark slate gray.

1. In general, are the inner or outer walls of craters steeper? Look at the shadows near the rims of the craters.

2. As a rule, do the peaks of craters tend to be above, level with, or below the level of the surrounding region? Give an example (Look at 12° S, 26° E.)

3. Do most large craters have peaks in the center? Give 3 examples that do.

4. In which quadrants (NE, NW, SE, SW) of the Moon are most of the craters found?

5. In general, do mountain ranges follow around the largest craters?

6.. Look at the crater Stofler. Is there evidence of other craters deforming the wall of Stofler? Sketch this crater and the surrounding region.

7. Locate 3 other examples of the phenomenon in #6. Name them here, along with their latitudes and longitudes.

8. Sketch the Sinus Iridium (*Iridium, Sinus* in the map index). What do you think is the cause of its present form?

B. The great plains of the Moon were called Maria (Seas) by Galileo because he thought that they looked like they were covered with water. We now know that water cannot exist on the Moon's surface and that the Maria are filled with what was once lava.

9. Name 2 or more Maria that are quite detached from the others.

10. What is the general shape of the Maria?

11. In which quadrants (NW, NE, SW, SE) of the Moon do the Maria predominate?

12. Estimate the visible portion of the Moon's surface that is covered by the Maria.

13. Estimate the diameter of Mare Serenitatis using 3500 km for the diameter of the Moon. Show your work!

14. Find 3 examples of the breaking down of crater walls by encroaching lava flows. List them and give their latitudes and longitudes.

C. There are 3 major mountain ranges on the visible portion of the Moon: the Apennines, the Caucasus, and the Alps. Peaks in these ranges can reach to 20,000 feet above the surface.

15. In general, are lunar mountain ranges straight or curved?

16. Sketch the Straight Range (Montes Recti) which lies between Plato and Sinus Iridium. (50^o N, 20^o W).

D. Lunar Rays are bright streaks which radiate from points near a few of the craters. Look at the ray systems of Tycho, Copernicus, and Kepler. These are best seen during the Full Moon (when the Sun is directly overhead that part of the Moon).

17. Do the rays cast shadows?

18. What does this indicate about their height?

19. Do rays pass equally well over crater walls, mountains, and plains?

20. Estimate the length of the longest rays from the crater Tycho in kilometers. Show your Work!

E. Rills are of the order of 1/2 mile in width and 500-1000 feet deep. Some are straight for hundreds of miles. They are most likely ancient underground lava tubes which have collapsed.

21. Sketch the regions south of Mare Vaporum and Mare Tranqulitatis. Label the rilles with their names

<u>MARE VAPORUM</u> <u>MARE TRANQUILITATIS</u>

22. Make a sketch of the Alpine Valley (Valles Alps). (50° N, 5° E)

F. Other features:

23. Sketch carefully the chain of features between Eratosthenes and Copernicus.

24. In the case of crater overlap discussed in previous questions, did large or small craters occur first? What does this tell you about the cratering history of the Moon?

25. Check the following craters. What is the height of each peak? Are the peaks higher than the rim of their craters?

Cyrillus

Theophilus

Albategnius

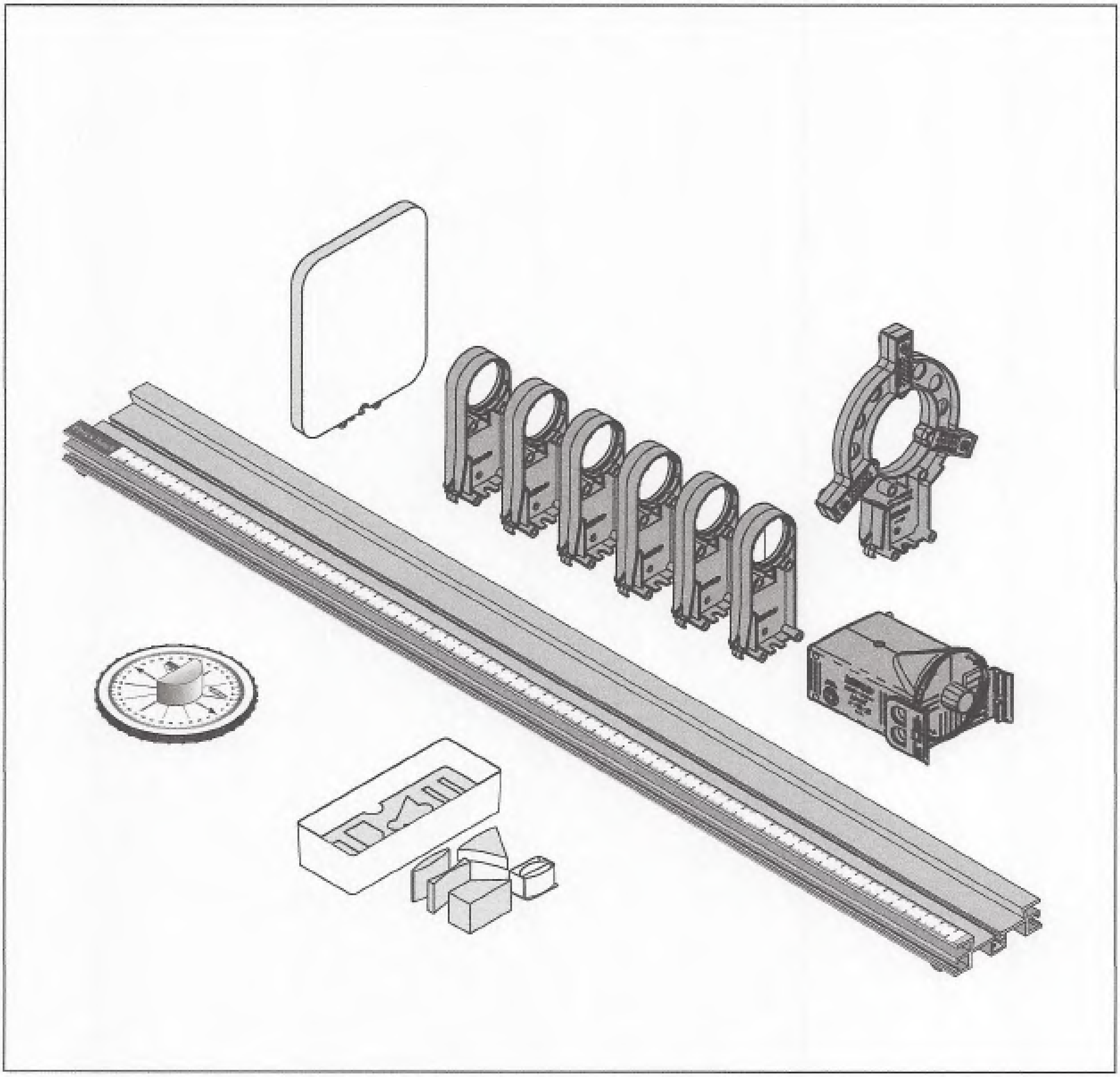
PASCO®

THE TABLE OF CONTENTS IS ON THE NEXT PAGE. THE FULL 71-PAGE MANUAL WILL BE SENT IF REQUESTED BY THE NATURAL SCIENCES SUBCOMMITTEE

Instruction Manual with Experiment Guide and Teachers' Notes
012-09900B

Basic Optics System

OS-8515C



Name______________________________

Observing the Solar System with *Astronomy* Magazine

I. Introduction

Each issue of *Astronomy* contains a center section that contains some useful information for observing the night sky during that month. This lab will familiarize you with this Sky Almanac and how to get the maximum information from it.

II. The Visible Night Sky

This is at the top of the planetary section of the Sky Almanac and depicts almost the entire night sky for the month. The extreme northern and southern skies have been omitted. Notice that the map covers more than 360° of the sky. Since the sky appears to rotate from East to West when facing South, the map allows the observer to use the right-hand side of the map during the evening and the left side of the map near dawn.

Notice the straight, blue line that runs horizontally across the center of this map. This is the **Celestial Equator**. The Celestial Equator is the projection of the Earth's equator onto the Celestial Sphere. The red-orange sinuous line is the **Ecliptic.** This is the apparent path of the Sun across the sky during the course of a year. That is, if you were to mark the position of the Sun among the stars every day at the same time of day for a year, this is the path you would draw. The Ecliptic can also be defined as the plane of the Earth's orbit around the Sun. Notice that if you were to fold this map into a cylinder, the Ecliptic and the Celestial Equator would form two circles that intersect at an angle of 23.5°. Note that this is the identical angle that the Earth's axis of rotation makes with the plane of its orbit.

The path of the Moon is denoted on this map as a sinuous pale, aqua line that nearly parallels the Ecliptic. The phases of the Moon for each day of the month are shown below the map. You can find the position of the Moon among the stars for any given date by drawing a vertical line from the Moon phase for that date upward until your line intersects the path of the Moon.

The paths of the planets and various comets and asteroids are also depicted here. The arrows for each object denote the direction and extent of motion during the month for that object.

III. The Table of the Planets

The table below the visible night sky map gives some observational data for each planet for the month. Remember that **Magnitude** is a measure of the brightness of an object with small numbers being brighter than large magnitude numbers. In a completely dark sky, the human eye cannot see beyond approximately 6th magnitude. The diagrams of each planet are to scale and depict the illumination and orientation of each planet. Notice that South is up in this diagram since astronomical telescopes invert their images. **Illumination** is the % of the planet's disk that is lit by the Sun.

IV. Jupiter's Moons

The lower left diagram is a representation of the motions of Jupiter's 4 largest moons for the month. These four moons are called the Galilean moons after their discoverer, Galileo Galilei. Each moon is shown in a different color with Jupiter in the center of the diagram. The numbers to the left of the diagram correspond to days of the month. The relative orientation of the moons and their relative distances from Jupiter are shown for each day of the month. Again, South is at the top, as it would be when viewing the Jovian system through a telescope.

V. The Planets in their Orbits

The lower right diagram shows some "bird's eye" views of our solar system. I.e.., if you could place yourself above the plane of the Ecliptic, this is what you might see. The sizes of the orbits of the planets are to scale for each diagram. The arrows for the inner planets show the direction of motion of the planets, the relative positions of the planets, and the length of the arrows show the fraction of their orbits each planet completes during the month.

The diagram depicts events such as **Elongations** (the farthest a planet appears to get from the Sun, denoted as either East or West depending on which side of the Sun the planet is), **Opposition** (the Sun and planet are separated by 180°- opposite in the sky), **Conjunction** ("in line with"), or **Quadrature** (Sun and planet make a 90° angle).

VI. Questions

1. What Zodiacal constellation(s) is the Sun in this month?

2. In the evening is the ecliptic north or south of the celestial equator? What does this imply about the location of Sunset (direction-wise)?

3. Why are all of the planets' (and the Moon's) positions near the ecliptic, but not directly on it?

4. Which planets are visible with the naked eye in the evening sky this month?

5. Which planets are visible with the naked eye in the pre-dawn sky this month?

6. Which planet is farthest from the ecliptic this month? Is this distance always the same? Why or why not?

7. Which planets are not visible to the naked eye this month? Explain why for each.

8. When is the Full moon this month?________________

New moon?_____________

First Quarter?____________

Last Quarter?____________

9. In what direction (East to West, or West to East) does the Moon travel during the month with respect to the stars?

10. What is the Sun doing when the full Moon is rising?______________

What is the Sun doing when the new Moon is rising?______________

11. What planet is the brightest this month? _____________

Which planet has the largest angular size?____________

12. Which planet is closest to the Earth this month?

13. Which Jovian moon is closest to Jupiter?

14. Determine the approximate orbital periods for the 4 Galilean moons from the Jupiter's Moons diagram.

Io________ Europa_________ Ganymede___________ Callisto________

15. Are any planets near conjunction or opposition this month? Which ones and when?

16. Calculate the orbital period of Mercury and Venus using the Planetary Orbit diagram. Explain your method!

Name ___________________________

Altitude of a Meteor

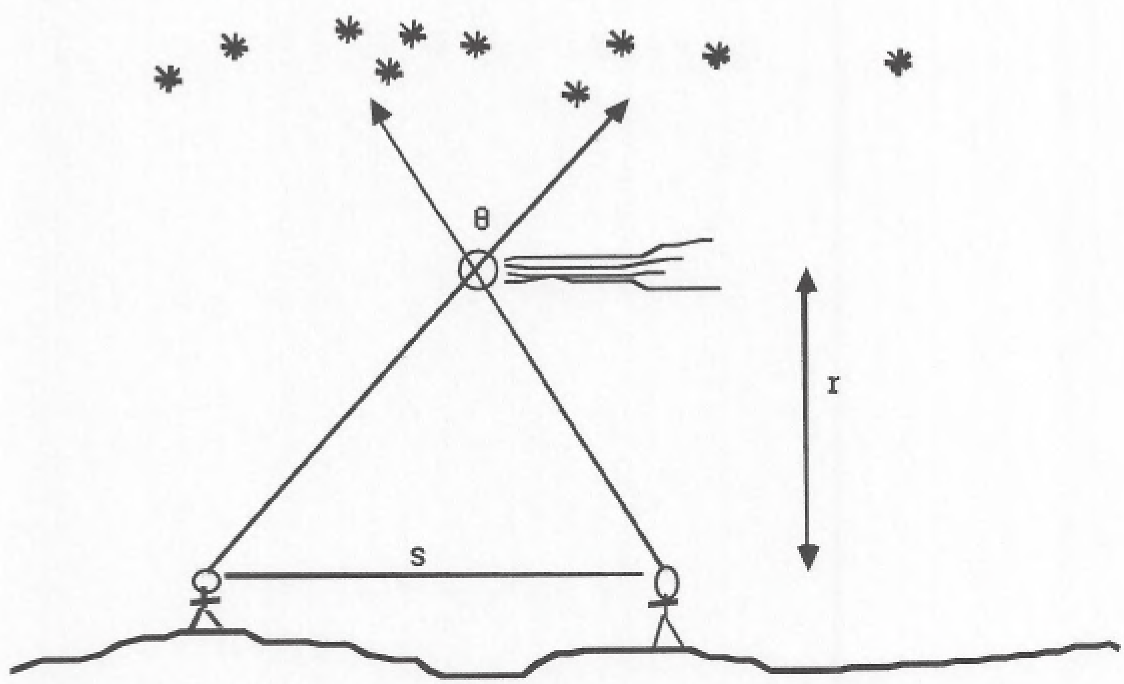
I. Introduction

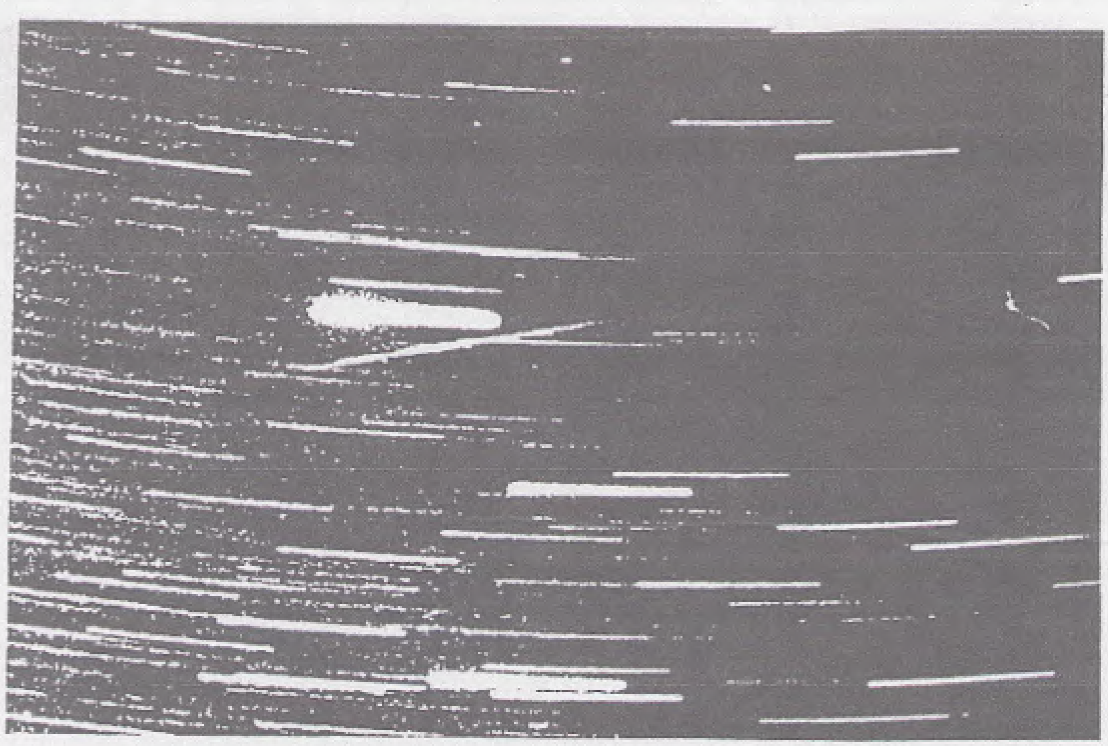
Man has been fascinated by meteors, or "shooting stars," since ancient times. In trying to determine the nature of meteors, one question that comes to mind is whether they are a phenomenon among the stars (or planets) or are they associated with the atmosphere?

II. Method

It is possible to calculate the altitude of a meteor (its height above the surface of the Earth) using simple triangulation techniques. In the diagram below, the meteor is at a height "r" above the Earth. The two observers are separated by a distance "s" and the angular difference in the position of the meteor from the two observers is "θ." Simple trigonometry tells us then that

$$r = \frac{s \cdot 57}{\theta}$$





III. Procedure

The photographs on the next page were taken of the constellation Aurigae during the Geminid meteor shower of December 13, 1975 between 11:14 - 11:30 p.m. The bright star is Cappella. Down and to the right is Epsilon Aurigae and the bright double streaks below that are Eta and Zeta Aurigae (left and right, respectively). The two observers were 3.2 kilometers apart.

Determine the altitude of the meteor (shown as a diagonal streak in the photographs) using the following method:

1. Determine the angular distance between Epsilon and Zeta Aurigae from the table on the following page:

SHOW YOUR WORK

1. Declination of Epsilon Aurigae ______________________ (degrees, minutes)

2. Declination of Epsilon Aurigae ______________________ (decimal degrees, 2 decimal places)

3. Declination of Zeta Aurigae ______________________ (degrees, minutes)

4. Declination of Zeta Aurigae ______________________ (decimal degrees, 2 decimal places)

Angular distance (#2 - #4) ______________________ (degrees, 2 decimal places)

Table #1. Right Ascensions and Declinations of Stars in Aurigae

Star	Right Ascension	Declination
Cappella	05 h 13.0 m	+ 45° 57.0'
Epsilon Aurigae	04 h 58.4 m	+ 43° 45.0'
Eta Aurigae	05 h 03.0 m	+ 41° 10.0'
Zeta Aurigae	04 h 59.0 m	+ 41° 00.0'

2. Determine the distance from Epsilon to Zeta Aurigae in millimeters on one of the photographs:

Distance from Epsilon to Zeta Aurigae ________________ (millimeters)

3. Calculate the plate scale for the photographs:

SHOW YOUR WORK

$$\text{plate scale} = \frac{\text{Angular Distance from Epsilon to Zeta Aurigae (degrees)}}{\text{Distance from Epsilon to Zeta Aurigae (millimeters)}}$$

plate scale =__________________degrees/millimeter

4. Calculate the angle "θ" by measuring the difference in the positions of the meteor trail between the two photographs. Do this by drawing the bottom photograph's meteor trail onto the top photograph, in exactly the same position as it appears in the bottom photograph (when you are done, they should be parallel). Then measure the perpendicular distance separating the two trails.

SHOW YOUR WORK

distance between meteor trails = ____________________ (millimeters)

angle between meteor trails = θ = distance x plate scale from page 2

θ = angle between meteor trails = _______________degrees

5. Calculate the altitude of the meteor :

$$r = \frac{s \cdot 57}{\theta}$$

with s = 3.2 kilometers.

r = kilometers

IV. Questions

1. Would it be better to have the two observers farther apart? What factors affect this method if they are too far apart (say, 500 km)?

2. From your lab results, was the meteor in our atmosphere, a phenomenon among the planets, or farther out still? (Height of Earth's Atmosphere = 100 km)

3. Using your result from the lab and the fact that this meteor was traveling at 20,000 km/hr, calculate the minimum time (in **seconds**) it would take the meteor to strike the Earth if it made it to the Earth's surface. Show all calculations.

Name ________________________

The Sun and Sunspots

I. Introduction

Sunspots were first regularly studied by Galileo. He was able to prove that Sunspots were features on the face of the Sun itself and not objects which passed somewhere between the Earth and the Sun. We now know that Sunspots are manifestations of magnetic fields below the surface of the Sun. These magnetic fields interfere with the convection of material close to the surface, causing localized stagnations. This material then cools more than the surround regions and thus appears darker. Sunspots have temperatures around 3500 Kelvin while the average temperature of the Sun's surface is 5800 Kelvin.

Knowing that the Sunspots were on the Sun itself allowed Galileo to determine the rotation rate of the Sun by observing the motion of Sunspots as the Sun rotates on its axis. Using the included observations, you will do the same.

II. The Observations

A. The diagrams on the following pages are images of the Sun taken on successive days at the Big Bear Solar Observatory in Southern California. The images were obtained in visible light with a high-resolution CCD and the Vacuum Tower Telescope. The dates for each image are shown with each image.

B. Determine the Synodic rotation period of the Sun:

1. Choose a sunspot that is visible in several images. The longer the time the spot is visible, the better.

2. Using the *orthographic projection plate* supplied by the instructor, determine the Solar Longitude for your spot group for the first and last days it is visible. Record your data in Table 1 below.

Table 1. Sunspot Data

	Date	Longitude of Sunspot
First Observation		
Last Observation		
Difference		

3. Determine the time difference between observations in days and record in Table 1.

4. Determine the difference in longitude between the observations in Table 1 and enter it in Table 1.

5. Determine the *synodic* rotation period of the Sun as follows:

$$\text{Synodic rotation rate} = \frac{\text{Difference in Sunspot Longitude from Table 1}}{\text{Time difference between observations}}$$

Synodic rotation rate =

Synodic rotation rate = ______________degrees/day

$$\text{Synodic period} = \frac{360 \text{ degrees}}{\text{Synodic rotation rate}}$$

Synodic period =

Synodic period = _________________________ days

C. Since the Earth revolves around the Sun as the Sun rotates on its axis, to determine the true (sidereal) rotational period of the Sun, we must correct for the Earth's motion over the course of the observations. Determine the Sidereal rotation period for the Sun:

$$\frac{1}{\begin{array}{c}\text{Sidereal Period}\\ \text{in days}\end{array}} = \frac{1}{\begin{array}{c}\text{Synodic Period}\\ \text{in days}\end{array}} + \frac{1}{\begin{array}{c}\text{Earth's orbital period}\\ \text{in days}\end{array}}$$

Where the Earth's orbital period in days is 365.26.

$$\frac{1}{\begin{array}{c}\text{Sidereal Period}\\ \text{in days}\end{array}} =$$

Sidereal Period = ____________________ days
of the Sun

IV. Questions

1. Do Sunspots keep a constant latitude as the Sun rotates?

2. What do you notice about the shapes of the spots as they rotate into view?

3. Propose a logically convincing argument to prove that the spots are on the sun itself. (Hint: think about question #2)

Name ____ Section ________

Application Exercise: Distances to Stars Using Measured Parallax

Objectives

- ✓ Qualitatively state relative distances to stars based upon their parallax shift
- ✓ Describe the limits of the measured parallax method of determining distances to stars
- ✓ Find the mathematical relationship between the measured parallax of a star and its distance in parsecs
- ✓ Given the values of measured parallaxes for a list of stars, calculate the distances
- ✓ Measure the parallaxes of two stars, calculate the distances, and state the uncertainties in the measurements
- ✓ Summarize the method, giving an evaluation of its strengths and weaknesses

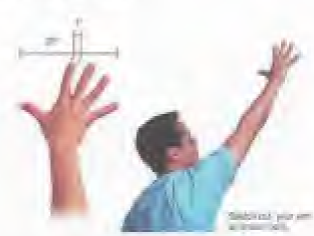
Materials

Scientific calculator
Rulers

Introduction

One of the most difficult problems in astronomy is determining the distances to objects in the sky. There are four basic methods of determining distances: radar, parallax, standard candles, and the Hubble Law. Each of these methods is most useful at certain distances, with radar being useful nearby (*e.g.*, the Moon), the Hubble Law being useful at the farthest distance (*e.g.*, galaxies far, far away). In this exercise, we investigate the use of the measured parallax method to determine distances to nearby stars, those within about 650 light years from the Sun.

Even when observed with the largest telescopes, stars are still just points of light. Although we may be able to tell a lot about a star through its light, these observations do not give us a reference scale to use to measure its distance. We need to rely on a method that you are familiar with: the parallax of an object.



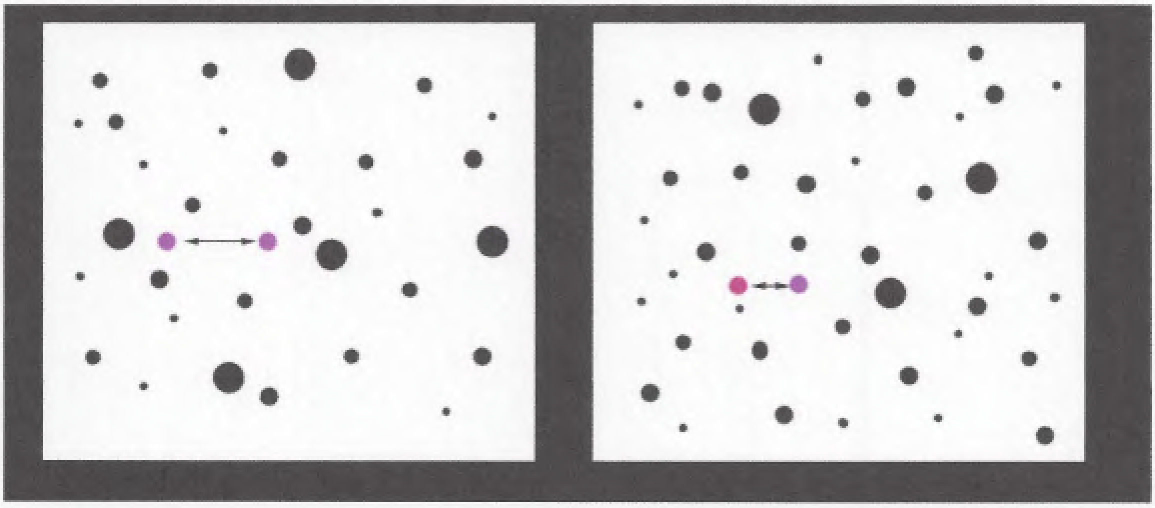
You can see the parallax effect by holding a finger out at arm's length. View your index finger relative to a distance background while you alternate opening and closing each eye. Does your finger seem to jump back and forth relative to the background? This is because the centers of your eyes are 5 – 6 centimeters apart, so each eye has a different point of view.

Because stars are **so** far away, and their parallax shifts so extremely small, the parallaxes are most conveniently measured in seconds of arc (arc seconds). The angular size of your index finger held at arm's length is about 1 degree. Imagine dividing this finger up into 3600 slices. One of these slices would represent the angular size of an arc second!

Without today's advanced observing techniques, measuring the parallax angle of even the closest star is impossible. The teachings of Aristotle (384 – 322 BC) and the mathematical model of Ptolemy (c. 140 AD) based upon Aristotle's universe, formed the foundation of astronomy for almost 1500 years. This universe was geocentric; it placed the Earth at the center (corrupt and changeable) of the heavens (perfect and immutable). Those astronomers who suggested that the Earth orbited the Sun were dismissed with the argument that if the Earth **did** orbit the Sun, the stars would show annual shifts, or a parallax. But, "...no matter how hard they searched, ancient astronomers could find no sign of stellar parallax." (*Bennett et al. The Cosmic Perspective, Addison Wesley, 2002*)

Part I: Sample Observations

Star Abba Star Babba



01. <2 pts>Represented here are observations of two different stars, Abba and Babba. Each is observed in January and then again in July; the observations are 6 months apart. Which star is closer to us? Explain how you know that based simply off of the picture.

02. <2 pts> Let's say that star Abba has a parallax angle about two times that of star Babba. What can we immediately determine about the relative distances of the two stars? Explain how we know this.

03. <2 pts > What if there were a star that had a parallax angle 1000 times **smaller** than that of star Babba? Assuming no advancement in our technology, would we still be able to detect a difference in its shift between January and July? What does this tell us about the limits of measuring parallaxes?

04. <2 pts> The limit to our measurements of parallax angles is about 0.005 arc seconds, or about 650 light years. The diagram at the right represents the Milky Way from a top-down view. Draw a circle on this diagram around the location of the Sun that indicates the range of usefulness of measured parallax. To what fractional part of the diameter of the Milky Way can we determine distances using this method?

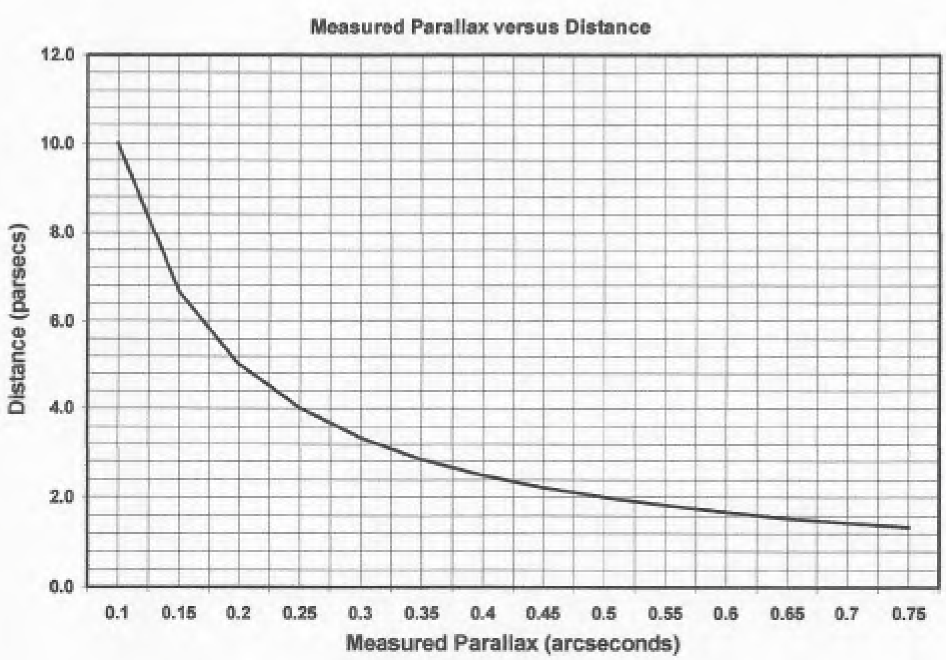
Part II: Mathematical Explanation of Parallax

05. <2 pts> One parsec is defined to be the distance to a star whose parallax angle is one arc second. If we have a star whose parallax angle is ½ of an arc second, its distance is 2 parsecs. If the star has a parallax angle of 3 arc seconds, its distance is 1/3 of a parsec. Based on this and the tutorial for this exercise, what is the mathematical relationship? (A word description is fine as well.)

____

____

____



06. <2 pts> The graph to the left shows the relationship between measured parallax and distance. Does the relationship match the mathematical description you found above? Check your answer from question 5 with this graph by choosing a parallax value and calculating the corresponding distance.

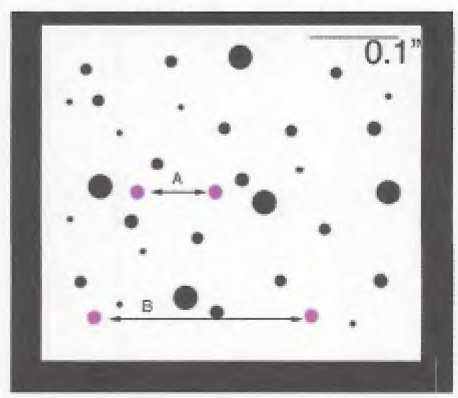
07. <2 pts> Below is a list of stars and their parallaxes. Rank use 1-4 where 1 is the nearest and 4 is the farthest.

Rank	Star Name	Parallax in arc seconds
	Antares	0.024
	Ross 780	0.213
	Regulus	0.045
	Betelgeuse	0.009

08. <3 pts> Complete the table below by calculating the distances to the stars. The formula for calculating the parallax is simply: $d = \frac{1}{p}$, where ***d*** is the distance in parsecs, and ***p*** is the measured parallax in arc seconds. Expressed another way: the distance in parsecs is just the inverse of the parallax in arc seconds.

Star Name	Parallax (arc seconds)	Distance (parsecs)
Arcturus	0.090	
Procyon	0.288	
Hadar	0.006	
Rigel	0.004	
Sirius	0.379	
Altair	0.194	

09. <3 pts> The image below is a sample observation of two stars in the same field observed 6 months apart. We combined two images so you could see the shift the stars made in this time. The scale in the upper right corner represents an angle of 0.1 arc seconds (not 0.1 inches).



What is the total angular shift for each star over this time period?
A _______ B _______

What is the parallax angle for each star?
A _______ B _______

What is the distance to each star, in parsecs?
A _______ B _______

III. Scientific Uncertainties in measurements

10. <2 pts> How uncertain are you in your results for question 9 using this method? That is, how far off could your values be due to measurement errors? Discuss briefly why there is this uncertainty.

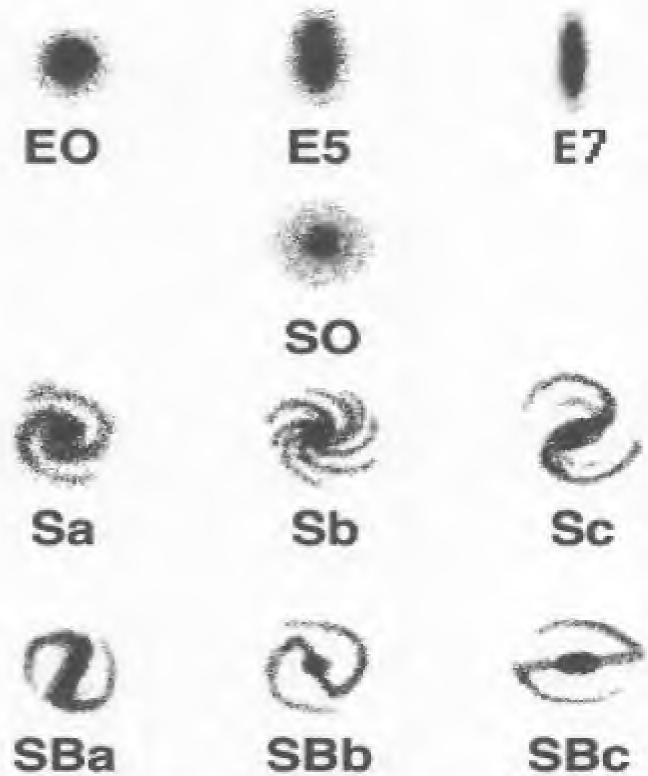
SOURCE: http://haydenplanetarium.org/universe/duguide/mwg_err.php				
Star Name	**Parallax Angle**	**Distance**	**Distance**	**Uncertainty Range**
	(arcsecs)	**(parsecs)**	**(light-years)**	
Ain (ε Tauri)	0.021	48	155	149-161
Bellatrix (γ Orionis)	0.013	75	243	226-262
Spica (α Virginis)	0.012	80	262	245-282
Betelgeuse (α Orionis)	0.009	113	368	352-544
Polaris (α Ursae Minoris)	0.008	132	431	405-460
Antares (α Scorpii)	0.007	144	469	460-876
Rigel (β Orionis)	0.004	237	773	648-956
Deneb (α Cygni)	0.002	660	2,150	2,063-7,409

11. <3 pts> Review the information in the above table. What do you notice about the relationship between the distance to a star and the uncertainty connected with that distance measurement? Discuss briefly whether or not this trend makes sense, and why astronomers would still use a measured parallax distance even though the uncertainty is very high.

Part IV: Summary

12. <5 pts> Explain to an incoming Astronomy 101 student about measured parallax: What are measured parallaxes used for? For how far away are they useful? How does one measure a stellar parallax? What are the strengths and weaknesses of this method? Use good writing style in this summary.

HUBBLE GALAXY CLASSIFICATION



Summary

In this exercise, you will learn to classify galaxies using the Hubble Classification scheme. You will also find their distances using the Hubble law.

Background and Theory

A galaxy is an assembly of between a billion (10^9) and a hundred billion (10^{11}) stars. In addition to stars, there is often a large amount of dust and gas, all held together by gravity. The Sun and the Earth are in the Milky Way Galaxy (sometimes referred to as "the Galaxy"). Galaxies have many different characteristics, but the easiest way to classify them is by their shape (or "morphology"), and Edwin Hubble devised a basic method for classifying them in this way. In his classification scheme, there are three types of galaxies: spirals, ellipticals, and irregulars.

- Spiral galaxies were the first to be discovered, because the most luminous galaxies close to the Milky Way are spirals. These galaxies get their name from the spiral distribution of light seen in photographs. A subclass of spirals contains the barred spirals. Ordinary spirals have a nucleus which is approximately spherical, while barred spirals have an elongated nucleus which looks like a bar. Spirals are labeled as Sa, Sb, or Sc; barred spirals are designated SBa, SBb, or SBc. The subclassification (a, b, or c) refers both to the size of the nucleus and the tightness of the spiral arms. The nucleus of an Sc galaxy is smaller than in an Sa galaxy, and the arms of the Sc are wrapped more loosely.
- Elliptical galaxies are classified according to the relative sizes of their apparent major and minor axes. Thus if x and y are these apparent axes, an elliptical galaxy is classed as En where

  $$n=10\cdot(x-y)/x.$$

  All elliptical galaxies have n between 0 and 7.
- Irregular galaxies have no obvious spiral or elliptical structure. It is thought that many irregulars were once spiral or elliptical, but that a close encounter with a larger galaxy disrupted the organization of the material by gravitational forces. Irregular galaxies come in two flavors: Irr I's are resolvable into individual stars, and Irr II's are not.

Not all galaxies are easily classified. Quasars are the bright, superluminal cores of very distant active galaxies. These galaxies are so distant in fact, that the quasars look like stars in most images. However, their **redshifts** are so high that we know that they can not be stars. These quasars are moving away from us at extremely high velocities. Quasar 3C273, for example, is moving away from us at 43,700 km/s!

The relationship between galaxy types is not clear. Because there is little evidence of star formation in elliptical galaxies, and because they seem to have extremely small angular momentum, it was thought that perhaps elliptical galaxies are much older than spirals. If this is true, then we would expect to see more spiral galaxies as we look farther out into the universe (that is, back in time). Recent observations made by Hubble Space Telescope *do* show more spirals in distant clusters of galaxies, however, there are also many more distorted galaxies and blue irregulars with enormous star formation rates.

regions are more likely to form ellipticals. The entire problem is not yet well understood, and many explanations rely heavily on the postulated existence of dark matter.

In the late 1920's, Edwin Hubble discovered one of the most fundamental properties of the universe, namely that it is expanding in all directions with a speed proportional to the distance. He used the redshift of spectral lines from distant galaxies (calculated by Slipher) whose distances could be determined by other means (for example, by Cepheid variable observations or measuring the angular sizes of HII regions). He interpreted the observed spectral shift as a Doppler shift, and determined that all galaxies (except a few very close ones that are in the same group of galaxies as the Milky Way) are receding from the Milky Way Galaxy with speeds proportional to their distances:

$$v=H\cdot d,$$

where d is the galaxy's distance (in Mpc), H is Hubble's constant (with a modern value of about 65 km/s/Mpc), and the speed v is found from the Doppler shift of the galaxy.

Procedure

Print out the worksheet.

1. Examine the images of each of the galaxies listed in the table below. When there is more than one galaxy in the image, use the finding chart to identify the galaxy in question. Identify each galaxy's type. Estimate the subgroup of the spirals, and measure the major and minor axes of the ellipticals so that you can calculate n and find the subclass. Use any scale you like to measure the major and minor axes, but be sure to measure both axes on the same scale. *Note: you only need to measure the axes for the elliptical galaxies!*

Galaxy images							
NGC 1381	NGC 1398	NGC 224	NGC 3031	NGC 3384	NGC 4374	NGC 4435	NGC 4486
NGC 4565	NGC 4594	NGC 4736	NGC 5055	NGC 5194	NGC 5236	NGC 7331	3C273

2. Use the Hubble constant and the formula given in the Background and Theory section to find the distance to each galaxy. Convert the distance from Mpc to light years. (1 Mpc = $3.26\cdot10^6$ l.y.) Converting to light years gives the amount of time the light traveled between leaving the galaxy and arriving at the telescope.
3. Check to make sure that all of your answers make sense. For example, check that none of the galaxies' light has been traveling for more than the age of the Universe. It is often difficult to make astronomical numbers meaningful. For each of the galaxies, indicate what was happening in the Earth's history when the light left that galaxy. For reference, the dinosaurs became extinct about 65 million years ago, Pangaea split into multiple continents about 200 million years ago, the Earth is about 4.5 billion years old, and the Universe is about 15 billion years old.
4. The velocity of NGC224 is negative. What does this mean? What are the implications for applying the Hubble Law to this galaxy?
5. 3C273 is one of the brightest radio sources in the sky. But the type of galaxy 3C273 is impossible to find from these images. Does this make sense? *Hint: Look at the distance...*
6. Look again at the color image of ngc5194. What color are the arms? What color is the bulge? Explain the colors that you see.

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Hubble Galaxy Classification

Galaxy Name	x	y	Type	Velocity (km/s)	Distance (Mpc)	Light Travel Time (yrs)	Earth-history Reference
NGC 1381				1630			
NGC 1398				1299			
NGC 224				-59			
NGC 3031				95			
NGC 3384				642			
NGC 4374				854			
NGC 4435				793			
NGC 4486				1180			
NGC 4565				1122			
NGC 4594				963			
NGC 4736				329			
NGC 5055				587			
NGC 5194				565			
NGC 5236				337			
NGC 7331				1105			
3C273				43,700			

1. The velocity of NGC224 is negative. What does this mean? What are the implications for applying the Hubble Law to this galaxy?

2. The type of galaxy 3C273 is impossible to find from these images. Why?

3. Look again at the color image of ngc5194. What color are the arms? What color is the bulge? What do these colors tell you about the stellar populations in these regions?

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