AAVSO Variable Star Astronomy
Web version of Hands-On Astrophysics

\[ m-M = 5 \log_{10} \left( \frac{d}{10} \right) \]

An educational program created by
The American Association of Variable Star Observers
funded in part by
The National Science Foundation

Project Co-Directors
Janet Akyüz Mattei
The American Association of Variable Star Observers
John R. Percy
Erindale Campus, University of Toronto

Curriculum Author
Donna L. Young
Lead Educator: Chandra EPO/SAO/NASA
The American Association of Variable Star Observers, Cambridge, Massachusetts, U.S.A.
AAVSO Variable Star Astronomy

49 Bay State Road
Cambridge, MA 02138
U.S.A.
Phone: 617-354-0484
Fax: 617-354-0665
e-mail: aavso@aavso.org
World Wide Web: http://www.aavso.org

Copyright ©1997/2008
by The American Association of Variable Star Observers

May be reproduced for non-commercial educational use.

AAVSO Variable Star Astronomy was prepared with the support of the National Science Foundation, Grant No. ESI-9154091.

AAVSO VARIABLE STAR ASTRONOMY

Project Staff
Janet Akyüz Mattei  Project Co-Director
John R. Percy  Project Co-Director
Donna L. Young  HOA Manual Author
Michael Saladyga  Project Facilitator
Karin Hauck  Production, Design, & Layout Assistant Editor
Lynn Matthews Anderson  Production Editor

Astrophotography
John Chumack

Charts
Charles E. Scovil  Editor and Production Coordinator, Asst. Editor
Kerrianne Malatesta  Finder Slide Production
Sara J. Beck

Contributors
Jeffrey S. Lockwood  Grant Foster
Janet A. Mattei  Michael Saladyga

Slide/Print Production
Michael Saladyga  Coordinator, Editor
Sara J. Beck  Associate Editor
Alan Asadorian  Slide Production
David Landry  Print Production

Software
Grant Foster  VSTAR
Michael Saladyga  HOAENTER, HOAFUN

Teacher Workshop Participants/Evaluators

Workshop 1 (1994)
- Henry Bouchelle  Ardis Maciolek
- M. Kathleen Cochrane  L. Rob Ochs
- Daniel Francetic  Michael Richard
- Michael Hoke  Sharmi Roy
- Carl Katsu  Edward Ruszczyk
- James Kormoham  Gary Sampson
- Paul Lee  Judith Stoltz
- Jeffrey S. Lockwood  Sallie Teames

Workshop 2 (1995)
- B. Steven Albert  Kristine Larsen
- Roger Bennatti  George Leonberger
- Glenn F. Chaple, Jr.  Francis M. Mikan
- John Clarke  Parker E. Moreland
- Mary Dombrowski  S. Hughes Pack
- Philip Dombrowski  Brian Rogan
- Gita Hakerem Foster  Joseph Wesney
- Alan Hirshfeld  Donna L. Young

Education Advisory Board
Walter Bisard  Central Michigan University, MI
W. Russell Blake  Plymouth Carver School, MA
Brendan Curren  Bronx High School of Science, NY
Marie East  Sudbury, MA
Linda M. French  Park School Corporation, MA
Christopher Harper  Phillips Exeter Academy, NH
Jennifer Hickman  Phillips Academy, MA
Darrel B. Hoff  Luther College, IA
Arthur Johnson  Harvard University Education Dept., MA
Jeffrey S. Lockwood  Tucson, AZ
Janet A. Mattei  Director, AAVSO
George S. Mumford  Tufts University, MA
Jay M. Pasachoff  Williams College, MA
John R. Percy  Erindale Campus, University of Toronto
Robert F. Tinker  Technical Education Research Ctr, MA
Charles A. Whitney  Harvard-Smithsonian Center for Astrophysics, Cambridge, MA
Anne G. Young  Rochester Institute of Technology, NY

Web Site Development
Scott Battaion  The Wright Center for Innovative Science Education, Tufts University, Medford, MA

Artwork
Lynn M. Anderson  Miranda Read
Lola Chaisson  Michael Saladyga

Equipment and Facilities:
- Sheridan College, Oakville, Ontario, Canada
- The Edit Sweet, Toronto, Ontario, Canada

AAVSO Variable Star Astronomy
Proofreading
Elizabeth O. Waagen

Software testing
David J. Sworin Branko Miskov
Gene Hanson John E. Isles

Special thanks to:
Gerhard L. Salinger
Program Director, Instructional Materials Development, Directorate for Education and Human Resources, National Science Foundation

Additional thanks to:
Eric Chaisson
The Wright Center for Innovative Science Education, Tufts University, Medford, MA

The Department of Astronomy, and Erindale Campus, University of Toronto, and their students: Winnie Au, Laura Syczak, Monica Milanowski, Matt Szczesny, Sarah Thompson, and Lawrence Yu.

Marvin E. Baldwin
Chair AAVSO Eclipsing Binary Committee

Neil F. Comins, University of Maine at Orono

John E. Isles, Plymouth, MI

Initial AAVSO-HOA Web Site Developers
Leora Aimee Hurwitz
Elena Khan
William Mackiewicz

Organizations
National Science Foundation
American Association of Variable Star Observers
University of Toronto, Erindale Campus, Ontario, Canada
Sheridan College, Ontario, Canada
Fondation Dudley H. Wright, Geneva, Switzerland
Harvard-Smithsonian Center for Astrophysics
Harvard College Observatory
Amateur Telescope Makers of Boston
National Aeronautics and Space Administration
Space Telescope Science Institute
Comité de Liaison Enseignants Astronomes, France Astronomical Society of the Pacific

AAVSO Staff Contributors
Lynn M. Anderson Karuna Kramer
Sara J. Beck Kerriann Malatesta
Grant Foster Janet A. Mattei
Tanja Foulds Michael Saladyga
Karim Hauck Elizabeth O. Waagen
Shawna Hutchings Theodore Wales

HANDS-ON ASTROPHYSICS VIDEOS

Writers Film Crew
John R. Percy David Tucker, Executive Producer
Janet A. Mattei Todd Hallam, Producer/Director/Editor
Michael Saladyga Mark Dury, Camera/Lighting
Todd Hallam Karl Dipelino, Audio
David Tucker Sylvie Charland, Narrator

Video Animations
Dana Berry, The Wright Center for Innovative Science Education, Tufts University, Medford, MA

Additional photography
Terence Dickinson Jack Newton

Featured in HOA Videos
Mary Dombrowski
Amateur Astronomer, High School Student, Glastonbury, CT
Christopher Sousa
Amateur Astronomer, High School Student, Glastonbury, CT
Glenn F. Chaple, Jr.
Amateur Astronomer, Science Teacher, Townsend, MA
Gerald P. Dyck
Amateur Astronomer, Music Teacher, Assonet, MA
Peter Garnavich
Astronomer, Harvard-Smithsonian Center for Astrophysics, MA
Owen Gingerich
Astronomer/Historian, Harvard-Smithsonian Center for Astrophysics
Martha L. Hazen
Astronomer and Archivist, Harvard College Observatory, MA
Imelda B. Joson
Amateur Astronomer, Editor, Burlington, MA
Robert P. Kirschner
Astronomer, Harvard-Smithsonian Center for Astrophysics, MA
Stephen P. Knight
Amateur Astronomer, Farmer, Waterford, ME
Brewster La Macchia
Amateur Astronomer (photometrist), Andover, MA
David W. Latham
Astronomer, Harvard-Smithsonian Center for Astrophysics, MA
Wayne M. Lowder
Amateur Astronomer, Physicist, Valhalla, NY
Brian G. Marsden
Astronomer, Harvard-Smithsonian Center for Astrophysics, MA
Janet A. Mattei
AAFSO Director, Astronomer, Cambridge, MA
E. Talmadge Mallen
Amateur Astronomer, Editor, Lynn, MA
Mario Motta
Amateur Astronomer, Cardiologist, Lynnfield, MA
John R. Percy
Astronomer, University of Toronto, Ontario, Canada

Additional Video Participants
Edwin Aguirre David Kochuk Terri Olsen
Thomas Appling Michael Mattei John Reed
Lee Budryk Scott Melanson Robert Simmons
Robert Collara Andrea Motta HOA Teachers
Carol Dombrowski Joyce Motta Kristine Larsen
Philip Dombrowski Justin Motta Sharmi Roy
T. Helga Dyck Melissa Motta Judith Stolz
Scott Kenyon Richard Nugent Donna L. Young

AAVSO Variable Star Astronomy
Preface

Through the years, the American Association of Variable Star Observers (AAVSO) has been a source of information and guidance to students who decide to study variable stars for class or science fair projects. The idea to develop a formal curriculum using the AAVSO’s unique variable star database, however, came about when I attended “An Education Initiative in Astronomy” workshop, supported by NASA, in Washington, DC, in February of 1990. The opportunities, objectives, strategies, and recommendations that were discussed at that workshop, along with the presentation by Dr. Bassam Z. Shakhashiri, then Director of the National Science Foundation’s Education Division, who suggested that we as astronomy educators have the best tools to attract the attention and imagination of students, other teachers, and the public, provided the impetus and ideas for Hands-On Astrophysics.

My colleague John R. Percy, a leading advocate of astronomy education for decades, had been using AAVSO variable star observations in many projects for his students at the University of Toronto. Inspired by the Washington, DC, workshop, Dr. Percy and I, with the strong endorsement of the AAVSO Council, decided to develop together a curriculum—Hands-On Astrophysics—based on our many years of experience in guiding students, and utilizing many decades of AAVSO variable star observations.

Variable stars are stars that change in brightness, and these changes in brightness help us understand the nature and evolution of stars and galaxies. The study of variable stars is particularly suited to science, math, and computer education. Students can observe variable stars with binoculars, telescopes, and even with the unaided eye, and then can analyze the changes in brightness of the stars they observe by using the over 600,000 observations and the computer programs provided with Hands-On Astrophysics. As students discover the unique qualities and the oddities of a star’s behavior, they can find out more about “their star” through further research in the library and via the Internet.

With members in 45 countries, the AAVSO is the largest organization in the world dedicated to variable stars, and with over 8.5 million variable star observations from its founding in 1911 to the present, the AAVSO is custodian of the world’s largest database on variable stars. Many variable star observing groups around the world submit their observations to the AAVSO to be part of the AAVSO International Database, so they can be used by researchers and educators around the world. AAVSO members and observers range in age from eight to over 90, and come from all walks of life, but they all have one thing in common: a love of and curiosity about variable stars. These dedicated amateur astronomers have provided the unique component of the Hands-On Astrophysics curriculum—real data which can be used by students, teachers, and amateur and professional astronomers alike to discover the secrets of the stars, including our own Sun.

All components of the Hands-On Astrophysics curriculum were designed with the discovery process in mind. Our intention in offering this curriculum to you is to help students acquire fundamental science skills and to develop an understanding of basic astronomy concepts, to provide interdisciplinary connections, and to take students through the whole scientific process. It is our hope that while having fun in working with real data, students will develop more sophisticated math and computer skills. We further hope that Hands-On Astrophysics will foster among both students and teachers a love of and interest in one of the most fascinating branches of science—astronomy.
*Hands-On Astrophysics* is not just for students and teachers: it has been developed for everyone who is interested in astronomy and in learning more about the wonders and workings of the universe. HOA materials are suitable for amateur astronomers who wish to learn more about the fascinating nature of variable stars. There is a wealth of information which can be utilized for science projects, for astronomy club activities, and for family learning.

As Co-Directors of HOA, John Percy and I gratefully acknowledge the funding provided to the AAVSO by the Education Division of the National Science Foundation (NSF) through Grant No. ESI-9154091, which enabled us to develop this curriculum. We express our sincere thanks to Dr. Gerhard L. Salinger, NSF Instructional Materials Development Program Director, who recognized the potential of our project and provided us with his invaluable guidance and recommendations throughout its development.

We express our gratitude to the thousands of amateur astronomers worldwide who contributed observations to the AAVSO International Database—without their efforts we would not have the real data on which the HOA curriculum is based.

Finally, we recognize with deepest appreciation the efforts of Donna L. Young, lead teacher and principal author of the HOA Manual, and the invaluable contributions of many teachers, students, amateur astronomers, AAVSO staff members, and other individuals to the development of *Hands-On Astrophysics*.

Janet Akyüz Mattei  
AAVSO Director

Cambridge, Massachusetts, USA  
December 1997
Foreword

In November of 1996, I attended the second Hands-On Astrophysics (HOA) teachers’ workshop held at the Headquarters of the American Association of Variable Star Observers (AAVSO) in Cambridge, Massachusetts. At the time I was teaching astrophysics and AP physics at the Maine School of Science and Mathematics in Limestone, Maine (a new residential math and science magnet school for juniors and seniors). I was looking for that nonexistent middle-ground material for my astrophysics class—halfway between basic introductory astronomy content and calculus-intensive astrophysics. During that workshop, as I considered the preliminary HOA materials before me, I decided that the concept of variable star observation had the potential to be a truly innovative and exciting curriculum. I went back to the magnet school and introduced my students to the process of estimating magnitudes, plotting light curves, and constructing phase diagrams with the VSTAR software.

In northern Maine in the middle of winter, early evening temperatures are often -25 to -35°F. But the night sky is stunningly beautiful with frequent aurorae and myriad stars, and the winter cold did not deter my students. I literally could not stop some of them from making their nightly observations. Seeing their enthusiasm, the idea passed through my mind that I would like to develop some classroom materials for teachers based on what the AAVSO had begun.

A few months later I was granted a yearlong residential fellowship at the Wright Center for Innovative Science at Tufts University, directed by Eric Chaisson. At the same time, AAVSO Director Janet Mattei asked if I would be interested in working as a development consultant for the HOA curriculum, thereby contributing the perspective of a recognized master classroom teacher with extensive experience in state science initiatives and national workshops. I decided that my project for the year at the Wright Center would be Hands-On Astrophysics.

The more involved I became with HOA, the more excited I became over the potential that the curriculum held for so many students and teachers. For the past year and a half I have been extensively involved in rewriting some preexisting materials and making copious additions to the manual. I have made every attempt to ensure that the manual is as easy to use as possible for classroom teachers, and is as interesting as possible for students, amateur astronomers, and other individuals.

The HOA curriculum will not work for content-driven courses. Instead, it is a self-directed study, with minimal input from teachers, which involves students in real science. There is nothing artificial or arbitrary or contrived. Hands-On Astrophysics students will do science in exactly the same way that professional scientists do science every single day. There are no right or wrong answers: the process is everything. The content is assimilated along the way as necessary, not presented as long and tedious text. This curriculum empowers students to take charge of a learning process that is applicable to every facet of their lives, whether educational or personal. No other science is as interesting or fascinating as astronomy, and doing astronomy is more interesting and fascinating than reading about it. Students can gain incredible insight into the scientific process with nothing more than their eyes and the contents of this curriculum.

Hands-On Astrophysics is an invitation to embark upon a journey into the very hearts of stars—to listen to the rhythms of their pulsations, and begin to gain an understanding of the processes by which they evolve. Along the way, students will acquire the necessary
skills and knowledge to determine and comprehend the message encoded within starlight, but the strength and power of the journey is that it involves a complete immersion into the scientific process—the very foundation of how we construct knowledge. Those who undertake this journey will also realize an added benefit: an appreciation of the stellar inhabitants of our universe that may result in a lifelong avocation as an amateur astronomer, with the potential of making significant contributions to science.

Finally, *Hands-On Astrophysics* takes students out of the artificial confines of classroom walls to gather observational data from the night sky above them. This is where they will begin their own individual journeys to the stars and feel the same deep stirrings that our ancestors felt when they looked towards the stars. We have not lost our fascination for the night sky. The colored and dancing display overhead causes us to pause and reflect, invoking deep longings that take us back through millennia and connect us to our past. Our origins are in the stars, and so is our future. When we look up we feel connected to the grandeur of the sparkling array above us. And that is the final powerful interdisciplinary aspect of this curriculum—that both people and stars are connected, occupying their own places in time and space, living and dying together in the same universe.

I am proud to have had the opportunity to help in the development of *Hands-On Astrophysics*. I hope it has a major impact on astronomy education worldwide.

Donna L. Young  
HOA Manual Author  
Curriculum Consultant

Medford, Massachusetts, USA  
December 1997
Table of Contents

CAUTIONARY SAFETY NOTE

UNIT 1: PLANETS AND STARS

CHAPTER 1: THE SOLAR SYSTEM AND BEYOND
An introduction to the nature, size, and scale of the Solar System and its place in the Milky Way Galaxy, along with some activities for expressing and visualizing these sizes and scales.

Investigations 1.1a–c: Sizes and Distances of the Sun, Earth, Moon, Planets
Core Activity 1.2: Unit Conversion
Core Activity 1.3: String Model of the Solar System
Core Activity 1.4: Mathematical Estimation of Sizes and Distances
Poster Page: An Arm’s-Length Reach Into the Universe (the Voyagers)
Space Talk on Objects in Our Solar System

CHAPTER 2: THE NATURE OF STARS
An introduction to the basic physical properties of stars that affect their appearance: apparent brightness, distance, temperature (seen as color), and the relationships among these properties.

Investigation 2.1: The Properties of Stars
Core Activity 2.2: Understanding the Temperature Scales
Investigation 2.3: How Bright Is It?
Core Activity 2.4: The Apparent Colors of the Night Sky
Poster Page: The Man Who Colors the Stars (David Malin)
Space Talk on Interstellar Distances

UNIT 2: INTRODUCING THE SKY

CHAPTER 3: FAMILIARIZING YOURSELF WITH THE NIGHT SKY
An introduction to “star hopping” and the planisphere—methods and tools which help students locate the constellations and determine when they are in the sky—as well as the Sky Gazer’s Almanac, which provides additional information on celestial events and times.

Investigation 3.1: Drawing a Star Map
Core Activity 3.2: Using the Planisphere
Activity 3.3: Searching for Constellations
Poster Page: Where to Go, What to Do.... (Navigating by the Stars)
Activity 3.4: Using the Sky Gazer’s Almanac
Space Talk on The Pawnee Sky Chart
CHAPTER 4: OUR BEARINGS IN THE SKY

This chapter describes and explains the apparent daily and yearly motions of celestial objects and introduces some simple activities to investigate and illustrate them. The celestial sphere model is introduced here, and the equatorial coordinate system is explained as one means of accurately locating objects in the night sky.

Investigation 4.1a: Understanding the Motions of the Earth–Moon System
Investigation 4.1b: Understanding the Motions of the Stars and Constellations…
Core Activity 4.2: Using a Quadrant to Measure the Motion of the Moon, Stars…
Core Activity 4.3: Why Constellations Appear in Different Places in the Sky…
Poster Page: Abe Lincoln and the Almanac Trial
Core Activity 4.4: The Rotating Earth and the Sun’s Apparent Motion Across the Sky
   a) Shadow Stick Astronomy
   b) Shadows on a Sphere
Core Activity 4.5: Constellation Plots
Activity 4.6: Plotting the Actual Positions of the Planets
Poster Page: Astrology or Astronomy? (Horoscopes and Precession)
Space Talk on Lunar Librations

UNIT 3: OBSERVING VARIABLE STARS

CHAPTER 5: INTRODUCING THE VARIABLE STAR ASTRONOMY CONSTELLATIONS

This chapter presents five constellations: Auriga, Ursa Major, Cygnus, Cepheus, and Cassiopeia. In the Northern Hemisphere, Auriga is a winter constellation, Cygnus is a summer constellation, and the rest are circumpolar. Students will investigate the stars and other celestial objects these constellations contain, and they will learn about some of the mythology associated with these constellations.

Investigation 5.1: The Magnitude of Stars in a Constellation
Poster Page: How Do You Keep Track of the Stars? (Star Catalogues)
Investigation 5.2: A Study of the Constellation Auriga, the Charioteer
Investigation 5.3: A Study of the Constellation Ursa Major, the Big Bear
Investigation 5.4: A Study of the Constellation Cygnus, the Swan
Investigation 5.5: A Study of the Constellation Cepheus, the King of Ethiopia
Investigation 5.6: A Study of the Constellation Cassiopeia, the Queen of Ethiopia
Poster Page: Astronomy is for Everybody
Space Talk on Variable Stars

CHAPTER 6: MEASURING VARIABLE STARS VISUALLY

This chapter is an introduction to identifying and making magnitude estimates of variable stars, using the slide and print sets accompanying the HOA curriculum. The classroom activities prepare students to successfully observe variable stars in the real sky, and to perform an accurate analysis of their data.

Investigation 6.1: Interpolation
Core Activity 6.2: Estimating Magnitudes Using Interpolation
Core Activity 6.3: How Accurate Are Your Results?
Poster Page: The Dangers of Radiation
Core Activity 6.4: More Magnitude Estimations
Core Activity 6.5: Collecting Your Own Data

AAVSO Variable Star Astronomy
CHAPTER 6: MEASURING VARIABLE STARS VISUALLY (continued)
Poster Page: Who Are the Amateur Astronomers?
Core Activity 6.6: Magnitude Estimation and Graphing with Slides (and/or prints)
Space Talk on Visual vs. Photoelectric Observational Data

CHAPTER 7: OBSERVING VARIABLE STARS IN THE REAL SKY
This chapter is the core of the Hands-On Astrophysics curriculum, introducing students to the process of variable star research. Students will be able to systematically observe bright variable stars such as delta Cephei and W Cygni.

Poster Page: Starlight In Your Eyes
Poster Page: Occupational Hazards of Variable Star Observing
Core Activity 7.1: Observing Your First Variable Star—Delta Cephei
Poster Page: She Discovered How to Calculate the Distances to Galaxies
Activity 7.2: Observing the Variable Stars W Cygni and Chi Cygni
Space Talk on Cepheids

UNIT 4: THE MESSAGE OF LIGHT

CHAPTER 8: THE NATURE OF LIGHT
An introduction to the basic physics of light and the rest of the electromagnetic spectrum, and how spectroscopic analysis of the colors within visible light gives information about chemical composition.

Investigation 8.1: The “Flavors” of Light
Core Activity 8.2: Spectra of the Elements
Core Activity 8.3: The Inverse Square Law
Poster Page: Inverse Square Relationships
Activity 8.4: Light Pollution
Space Talk on Rainbows

CHAPTER 9: THE LIFE OF A STAR
This chapter introduces the Hertzsprung-Russell (H-R) diagram, a graph depicting the stellar spectral types that represent the evolutionary stages of stars.

Investigation 9.1: The Continuous Spectrum
Poster Page: “The Most Original Thinker of All....” (Antonia Maury)
Core Activity 9.2: Plotting an H-R Diagram
Core Activity 9.3 (a & b): Variable Stars and the H-R Diagram
Poster Page: Planets or Stars?
Space Talk on Stellar-Like Objects Not on the H-R Diagram
UNIT 5: ANALYSIS OF VARIABLE STARS

CHAPTER 10: STATISTICAL CONCEPTS
This chapter introduces the statistical concepts necessary to analyze and interpret variable star data. Histograms, relative frequency, variability (range, average deviation, variance, standard deviation, the normal curve), and error bars are presented.

Investigation 10.1: Finding the Average
Core Activity 10.2: Constructing a Histogram
Core Activity 10.3: Finding the Average Deviation
Poster Page: Hands-On Universe
Core Activity 10.4: Variance and the Standard Deviation
Core Activity 10.5: The Standard Error of the Average—The Error Bar
Poster Page: Variable Star Mythology
Activity 10.6: Statistical Analysis of Delta Cephei
Math Talk on Uses and Misuses of Statistics

CHAPTER 11: VARIABLE STARS, LIGHT CURVES, AND PERIODICITY
This chapter discusses different types of variable stars and introduces light curves, the most important graphs in variable star astronomy. It discusses the characteristics of variable star light curves and demonstrates how to plot and interpret them.

Investigation 11.1: Recognizing Periodic Curves
Poster Page: Mapping the Universe (HIPPARCOS)
Core Activity 11.2: Analyzing the Light Curve for Star X
Activity 11.3: Analyzing the Light Curve for Delta Cephei
Core Activity 11.4: Pogson’s Method of Bisected Chords
Core Activity 11.5: VSTAR
Poster Page: Radar Guns and Speeding Stars
Space Talk on DI Her—A Puzzling Binary System

CHAPTER 12: VARIABLE STARS AND PHASE DIAGRAMS
This chapter introduces phase diagrams, which show the average behavior of a star during its cycle and determine the accuracy of the measured period. Mathematical and computer techniques for determining periodicity are also presented utilizing the VSTAR software program.

Investigation 12.1: Periodic Cycles
Core Activity 12.2: Folded Light Curve of the Variable Star SV Vul
Core Activity 12.3: Another Folded Light Curve of SV Vul
Core Activity 12.4: Yet Another Folded Light Curve of SV Vul
Poster Page: SS Cygni
Activity 12.5: Folded Light Curve of Star X and Delta Cep
Core Activity 12.6: VSTAR
Space Talk on Mira Stars
Poster Talk: “Theoretical Glue”
CHAPTER 13: VARIABLE STARS AND O-C DIAGRAMS

This chapter introduces the concept that processes that are periodic are predictable. For periodic variable stars, astronomers can use prediction to plan their observation of the stars, and also to look for deviations from periodicity. This chapter introduces the O-C diagram, which can determine deviations from predicted values.

Investigation 13.1: Constructing an O-C Diagram
Core Activity 13.2: Understanding O-C with Miras
Core Activity 13.3: Prediction of SS Cyg
Activity 13.4: Prediction and Observation of Delta Cep
Poster Page: Universal Models
Core Activity 13.5: Prediction and Analysis of the Period of R Cyg
Activity 13.6: O-C for Eclipsing Binary Stars
Space Talk on The Eclipsing Binary
Poster Page: The Birch Street Irregulars
CAUTIONARY SAFETY NOTE

1. Students should NEVER look directly at the Sun, especially when using binoculars or telescopes. The ultraviolet radiation from the Sun will damage the delicate cones and rods of the eye and can cause blindness. If students do not have specialized filters for solar observations provided or approved by their instructors, they should project the image of the Sun on the ground or a piece of paper.

2. Special precautions need to be taken for nighttime observations, whether at home or at school. Students should NEVER travel to or work alone in isolated areas. Make sure that the observational sites selected are safe, and always work with others. Inspect the chosen sites carefully, making note of any potential sources of danger such as construction areas, broken glass, etc. If working with power-driven telescopes outdoors, make sure that extension cords are properly grounded. If a site is located on private property, be sure to obtain permission (preferably written) from the owner ahead of time.

3. Parents or guardians of students should be informed of any assignments that students are required to do involving the observation of the sky, especially late at night. The proper school authorities should be notified, and permission slips signed by parents of younger students. Depending upon the age level of the students, one or more adults should accompany the group, such as parents, local astronomy groups, or amateur astronomers.