



Introduction to Photometry and Exoplanets

This course is a great way to discover what you are passionate about in the field of exoplanet research, gain experience before the American Association of Variable Star Observers AstrolmageJ (AAVSO) Exoplanet Observing course for NASA’s TESS, get into the JPL/NASA Exoplanet Watch program, or start your own exoplanet observation or analysis projects.

Prerequisites: Students must have completed the DoubleSTARS™ or have equivalent observational astronomy experience. In the latter case, students must have passed the IntroSTARS™ course and be approved by Boyce-Astro.

The Introduction to Photometry and Exoplanets course is split into three “Modules” over about eleven weeks and is self-paced and online. Each module has steps to cover the various topics, and a Zoom meeting in the beginning to cover questions and instructions. There will be two quizzes, at the end of Module 1 and Module 3. The instructional materials are largely online video presentations lasting 5 to 10 minutes to enable watching in moments of free time.

Course Calendar		
Module 1		Basic Photometry, an Exoplanet Overview and doing the TESS Planet Hunters on Zooniverse
Week	1	Class 1
Week	2	
Week	3	
Week	4	Quiz 1
Module 2		Do an exoplanet transit observation project using the Center for Astrophysics (CFA) MicroObservatory
Week	5	Class 2
Week	6	
Week	7	Draft Report for CFA
Module 3		More you need to know for doing your own exoplanet observations or for the AAVSO Exoplanet Observing course
Week	8	Class 3
Week	9	
Week	10	Quiz 2 mailed
Week	11	Quiz 2 due, Class 4

The course requires a computer with internet connection able to stream videos. The classes are held online using Zoom, a teleconferencing service, on week nights at 8:00. Students are invited to a Slack Workspace and Channel to communicate with class members and the instructor. Course materials will be available on a Google Drive. The two quizzes are sent to allow at least five days to complete before due.

Module I

STEP 1: INTRODUCTION TO PHOTOMETRY

Eleven videos are to be watched in Step 1. They are listed in the suggested order to watch but may be watched in any order. Click on the Topic and video to go to the YouTube video. Quiz 1 will be based largely on these training videos.

	Topic	Description
1	<i>HR Diagram Overview</i>	Learn the basic classification system for stars and their life phases
2	<i>Overview of light curves</i>	How light curves are made and help classify variable stars
3	<i>Telescopes an overview</i>	The types and how they work
4	<i>Instrumental Magnitudes</i>	How star magnitudes are measured with a CCD and telescope
5	<i>Airmass</i>	Observing through the atmosphere and how to correct for it
6	<i>Image Reduction</i>	How you correct CCD images for equipment imperfections
7	<i>Linear Saturation</i>	How CCDs respond to increasing the exposure times
8	<i>SNR</i>	What causes noise in images and how to measure its effect
9	<i>Aperture Photometry</i>	How to measure a star's light flux
10	<i>Differential Photometry</i>	How to measure a target star's changes in relative magnitude
11	<i>Comparison/Variable Stars</i>	What is a comp star and how do you find them

STEP 2: INTRODUCTION TO EXOPLANETS

Watch this video by Dr. Jessie Christiansen to learn about exoplanets and NASA programs:

Workshop "Kepler and TESS Opportunities"

An overview of exoplanet discoveries and the NASA programs to observe them (67 min).

STEP 3: TESS Planet Hunters on Zooniverse:

Zooniverse is a citizen-science crowd-sourced organization to help researchers go through actual data. In this Step use Zooniverse to make exoplanet observations for TESS

Watch "*How to do TESS Planet Hunters Observations on Zooniverse*" Create an account at <http://www.zooniverse.org> and make 15 Observations. Be sure to review all the materials provided such as for eclipsing binary stars.

STEP 4: Quiz

Expect to receive a Google Forms quiz early in Week 4 of the course with a due date at the end of Week 4.

Module 2

The Harvard / Smithsonian Center for Astrophysics (CFA)'s MicroObservatory is a way to make real exoplanet observations online in an environment with an easy user-interface. It is an introduction to taking your own images and analyzing them with a team. The website consists of a series of lessons and imaging activities, with the data you find eventually being published in the "community" section.

Harvard / Smithsonian Center for Astrophysics (CFA)'s MicroObservatory

Instructions will be given during the Module 2 Zoom meeting covering the Micro Observatory. The class will be split into teams of 3 to 5 depending on the number of students. Each team will be in charge of imaging a star to detect an exoplanet. There are more instructional materials in the Google Drive.

To begin the course, login with your provided login information provided in the Module 2 Zoom meeting. You can complete the modeling lab section on your own, but it is highly recommended to communicate with your team before the next steps (see next paragraph). It is also recommended to designate a team leader to maintain communication within the group. The Boyce Astro Zoom channel is available as a meeting space as well as the Slack channel.

To get an accurate light curve, every member of the team must take and measure 10-20 images, depending on the team size. The team will then have enough images to make an accurate light curve exoplanet transit (about 70-100 images/measurements). Then the team will need to assess the light curve to prepare a brief observation report on the planet's size and orbit.

Be sure to collaborate with team members if some images are not useable due to weather.

Module 3

Similar to Module 1, you have eight videos to watch at your leisure. Quiz 2 in Google Forms format about the content of the videos will be sent one week before the end of this Module.

	Topic	Description
1	<i>Light Curve Analysis</i>	What light curves can tell you about your target star
2	<i>Variable Stars HR Diagram</i>	Where variable stars fall on the HR Diagram and their lives
3	<i>Filters Overview</i>	The use of filters in astronomical imaging
4	<i>SLOAN ugriz filters</i>	The characteristics of Sloan Digital Sky Survey filters
5	<i>FITS Files</i>	The essential astronomical file structure and metadata
6	<i>FWHM</i>	How to use this measure to assess and improve your images
7	<i>What is BJD</i>	The basic time measure in astronomy
8	<i>Light Curve O-C Diagram</i>	How to find the period changes in variable stars and exoplanets

Additionally, please watch these videos to prepare you for future opportunities for exoplanet observations and Class 4.

How pro-am astronomers can contribute to exoplanet science (44 mins)

- Workshop "*Kepler and TESS opportunities Part 2*"

TESS and the role for pro-am astronomers in SubGroup 1 (22 min)

- Workshop "*Kepler and TESS opportunities Part 3*"

FINAL ZOOM MEETING (Class 4)

This will be a reflective meeting on the course and the available next steps in exoplanet research. Be prepared to describe what you would like to do going forward.

If students finish this course and pass both quizzes, Boyce Astro will fund their AAVSO membership and reimburse the cost of the AAVSO Exoplanet course if passed. Students need to volunteer for this when completing Quiz 2.

For Further Study:

1. General Exoplanet observation instructions and guidance: The best source of reference materials for this course and more is at www.astrodennis.com which is a living website maintained by Dennis Conti.
2. Doing the data reduction for an observation on your own: Transit Light Curve Tutorial by Andrew Vanderburg <https://www.cfa.harvard.edu/~avanderb/tutorial/tutorial2.html>
3. For further AAVSO Exoplanet Observing course preparation for TESS observations: These videos of Dennis Conti's presentation at the Boyce-Astro October 2016 Exoplanet Workshop are good for your preparation.
 - Part 1 (68 min)
 - Part 2 (78 min)
 - Part 3 (71 min)
4. Preparing for Exoplanet Watch with Boyce-Astro: For students who want to go directly to doing Exoplanet Watch observations and reports, the AAVSO Exoplanet Observing course is not required. If choosing this option, review materials in #1 above and do 2 above. Additional materials will be provided after completing# 2.