Dear Teacher,

You are about to involve your students in one of the most exciting frontiers of science – the search for other worlds—and life— in solar systems beyond our own! Using the MicroObservatory telescopes, built and maintained by the Harvard-Smithsonian Center for Astrophysics and located at the Whipple Observatory in Amado, Arizona, students will gather real data to see if they can detect actual alien worlds orbiting distant stars. Welcome to the *Laboratory for the Study of Exoplanets* (aka "*ExoLab*")!

GETTING STARTED

Web Browser with Flash Plug-In. This project is entirely Web-based. Students can work individually or in groups, but they will need access to a computer with a standard Web browser with the Flash plug-in. Most browsers already come with the Flash plug-in installed. If you can't see the labs when you click GO TO THE LAB, simply download Flash here. NOTE: We have discovered compatibility issues with some versions of Internet Explorer. For best results, use Chrome, Firefox, or Safari web browsers.

Sign Up For a Classroom Account. Click the SIGN UP button at the top right of any ExoLab page and follow the instructions to provide your school and class information, and then set up a Teacher username and password that you will use to access your classroom account. (For each class you want to engage in ExoLab, you will need to sign up for a *separate* classroom account, so you may want to number your usernames, e.g. MrsJones1; MrsJones2, etc). Once you submit your school and class information, our ExoLab Team will review the request and you will receive an email within 2 days when your account is approved. *The classroom account allows you and each of your students to take telescope images, and to store and retrieve individually personalized data and work from the project's database.*

Logging In and Registering Students. Once you have received your approval email, you will use the Teacher username and password you signed up with to LOG IN to the ExoLab from any page and then click on REGISTER to set up each of your students with a unique username and password. (Save the account approval email, which will have more detailed instructions on registering your students).

Online Student Database. When they are logged in, each student's account saves all their written comments, hypotheses, and answers to challenge questions within each Lab. Once they answer a question, it will automatically be saved to their account. Currently students can overwrite their answers and the journal will save only their most recent work.

Reviewing student's work. Because you as the teacher sets up and manages your students' usernames and passwords, you may review their work by logging in as each student and viewing their "My Results" pages. (Alternatively, you may ask students to take screen shots of

those aspects of the Lab you want them to hand in to you.) We are working on a feature to allow you to download a spreadsheet of student responses, but that is not currently available.

Additional Support for Teachers. The "For Teachers" link on the ExoLab home page contains additional materials, including the full Teachers' Guide, and a link to ExoLab Video Tutorials on YouTube.

SCHEDULING THE PROJECT

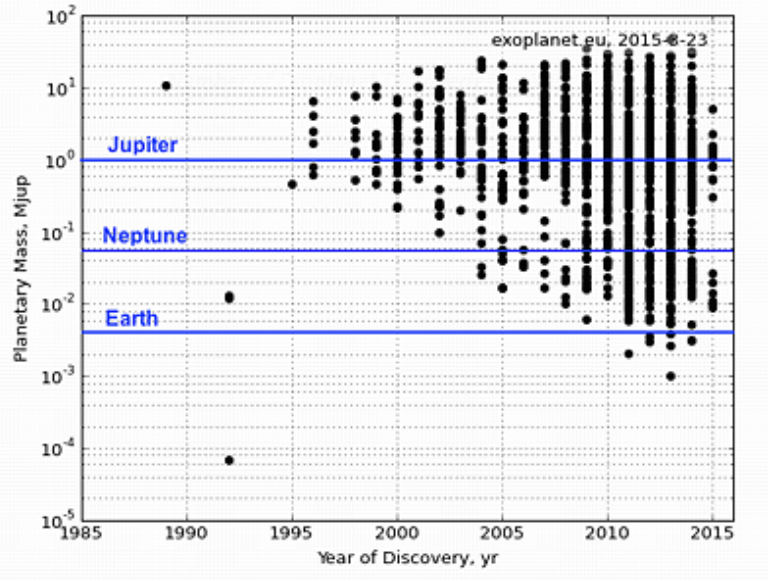
Time Required. This project requires 5 to 10 regular classroom periods (although some teachers have had students investigate multiple target stars to extend the project). You can start the ExoLab at any time, since there are exoplanets observable on practically every night of the year. For future planning, calendars of upcoming ExoPlanet targets are on the Teachers section of the ExoLab website, and get updated every couple months. ***IMPORTANT: Do the project once yourself first before engaging students!*** The ExoLab is *real* science, including all the unexpected turns that an authentic investigation may take. You'll be much better prepared to support your students if you experience the process of analyzing telescope image data yourself first.

Images Expire! Once you take your telescope images, *they will only remain accessible from the Website for 4 weeks.* (Student work - including measurements, graphs and written comments - remains on the Website without expiring.)

Plan for Clouds. Be aware, it may be cloudy when you take your images. If so, simply use the telescope again on another night. You may want to take images for several ExoPlanet targets during the week you begin, to raise the probability of getting good data.

Unlimited Access. There is no limit to the number of times you can access the telescopes, and no limit to the number of images you can take. (But remember, each image will be deleted from our server 4 weeks after you take it.)

Exoplanet Discoveries by Mass and Year



WHY THIS PROJECT?

Engages Students in Frontier Science. The ExoLab Project engages students in the exciting scientific search to answer the age-old human question: *Are we alone in the Universe?* Central to the search for extraterrestrial life is the hunt for other Earth-like planets. Since the first extrasolar planet was discovered in the 1990s, new planets have been detected at an accelerating pace. Most of those discovered to date are much larger than Earth, closer to their stars, and therefore fiery, uninhabitable places. However, scientists expect to find more and more Earth-like worlds, orbiting just the right distance from their star, in the very near future. That means it is highly likely that this generation will be the first to find life beyond Earth.

Supports Next-Generation Science Standards.
The ExoLab Project aims to create a model for how to integrate content learning with the practices of authentic scientific study. The project is designed to work in a variety of physics, astronomy, and earth science classrooms. To a significant extent, you will decide your students' specific learning objectives based on the content you intend to teach. However, all students should be able to develop and consolidate their knowledge and skills in the following NGSS-recommended areas:

NGSS Disciplinary Core Ideas explored in ExoLab (Earth Science; Physical Science)	**ExoLab students engage in these Scientific Practices**	**Cross-cutting Concepts encountered that apply across science domains**
Earth's Place in the Universe (ESS1.A & B) Electromagnetic Radiation (PS4.B) Information Technologies and Instrumentation (PS4.C)	Asking questions Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics, information and computer technology, and computational thinking Constructing explanations Obtaining, evaluating and communicating information	Size, scale, & proportion Systems and system models Patterns Cause and Effect

Fosters Data Literacy. The ExoLab is the real thing: the data that students collect are real, not canned. This means that students will learn to deal with the messiness of real data, and use the same kinds of analytical methods that professional scientists use every day to separate the *signal* from the *noise* in their investigations.

EXOLAB SEQUENCE OF ACTIVITIES
The core activities are outlined as follows:

Activity 1- **Introduction & Welcome to the Laboratory for the Study of ExoPlanets**
Welcome students to the community of planet hunters. Students explore the ExoLab website and share their ideas about the search for extraterrestrial life on other worlds

Activity 2 - **Modeling Lab**
Using a computer model, students predict the light curve of a star with an orbiting planet and consider how this model might inform their interpretation of their observational data.

Activity 3 – **Telescope Lab**
Students take images of stars known to have transiting exoplanets with the MicroObservatory telescope. *Image requests should be made during the day before each night's scheduled Exoplanet target observations*

Activity 4 – **Image Lab**
Students take measurements of the relative brightness of their star to create a light curve, and examine the factors that may affect the quality of their telescope image data.

Activity 5 – **Data Lab**
Students analyze the light curve using a "best fit" model to figure out the size of the planet and the nature of its orbit. Along the way they use methods for identifying a signal within noisy data, and consider how to use statistics and a modeling tool to draw conclusions from a light curve with considerable scatter.

Activity 6 — **Community**
This page on the ExoLab website allows students and teachers to post their own work, and to see the work of other schools participating in the project

TBD **– Visualization Lab**
In this Lab to be developed in the future, students will use all of the data they have collected to describe what they have learned about their planet. Then using an interactive computer-modeling tool, students will create a visualization of their planet.

TBD **– Color Lab**
This Lab, to be developed in the future, will enable students to engage in the *characterization* of extrasolar planets. Having now discovered thousands of exoplanets, researchers at this scientific frontier seek to glean the chemical and physical properties of these worlds, using spectroscopy to look for biosignatures.

Assessment
There are a number of opportunities throughout this project to assess students' progress. Embedded in the project are several products, which are recorded in the students' online account and can be assessed. Students are asked to make and test predictions using models and transit data they have collected and to explain their answers. Students are also asked to do mathematical calculations, the accuracy of which can be assessed. As a final assessment, you may wish to ask students to prepare a presentation, poster, or article describing their investigation. Try having them follow this typical format for scientific papers:

- Title—the subject and what aspect of the subject was studied.
- Abstract--summary of paper: The purpose of the investigation, the primary results, the main conclusions
- Introduction--*why* the study was undertaken, background
- Methods --*how* the study was undertaken
- Results--*what* was found
- Discussion--*why* these results could be significant (what the reasons might be for the patterns found or not found)

They may use screen shots from the ExoLab to illustrate their methods, data, etc.

BACKGROUND SCIENCE

Detecting extrasolar planets via the "transit method"
Astronomers have been hunting for planets that orbit stars similar to our own Sun. To date, they have confirmed detections of nearly 2000 of these new worlds (for the latest numbers,

go to http://planetquest.jpl.nasa.gov/). Only in very rare circumstances can astronomers use current telescopes to detect these planets directly. Instead, astronomers use indirect methods. One such method, used here in the ExoLab, involves detecting a planetary transit.

In a few cases, the orbit of an alien planet happens to be oriented so that the planet passes through our line of sight with the star. That is, the planet eclipses, or blocks, part of the star's light; once during each orbit. These are called transiting planets, because if we were closer we would see the planet transit across the face of the star.

How can a telescope be used to detect planetary transits?

Telescopes do more than take pictures – they gather light; and the images contain valuable information about the amount of light reaching the telescope from each star. It turns out that even a small telescope, such as the MicroObservatory telescope students will be using, is sensitive enough to detect a 2-3% drop in the amount of light reaching the telescope when the image is taken. To detect a transiting planet, you must take a series of images that span the timeframe of the entire transit; measure the brightness of the star in each of those images; plot it on a graph of time versus brightness; and look for the telltale dip in brightness that is the signal of the alien world.