[](http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit1/bright.html#content)

* **automated online quizzes** are low stakes and allow you to practice your mastery of the concepts in the lessons;
* **required participation in discussion groups** - your substantive posts on an assigned topic will allow me to gauge your progress and ability to articulate key concepts;
* **performance of homework and exercises** - you will investigate several different concepts by performing exercises , analysing summarising , and reporting your results;
* **a final project**that will be used to evaluate your knowledge and skills through the production of a learning module that you, in turn, will be able to use to teach a fully accessible course in astronomy your own students.

You will earn a grade that reflects the extent to which you achieve the course learning objectives listed above. Grades are assigned by the points earned in each lesson's activities.

The student is required to do a presentation during the final day of class. The student will choose the subject of the presentation. The subject has to be related to the life and death of stars.

As you may perceive from the breakdown of value percentage for each task you should perform as a student/participant the assessment process includes group and individual assessments. Group assessments means the work will be done in groups. The groups will be randomly formed by the digital platform and the deliverable turn in date may be either in the classroom same day or next day digitally.

Students are highly encouraged to disclose needs for accommodations of any and all kinds. This will be confidential and the needs of acommodation will only be communicated to the office in charge of providing such acommodation if needed.

| **Breakdown of each assignment's value as a percentage of the total course grade.** | |
| --- | --- |
| **Assignment** | **Percent of Grade** |
| Automated online quizzes: 3 | 25 % |
| Required participation in breakout digital discussions and completing practice problems | 25% |
| Home works | 25 % |
| Final Project | 25 % |

I will use ( name of system to keep track of your grades)…sorry I forgot

| **Letter Grade and Corresponding Percentages** | |
| --- | --- |
| **Letter Grade** | **Percentages** |
| A | 89 - 100 % |
|  |  |
|  |  |
| B | 78-88 |
|  |  |
|  |  |
| C | 77-87 |
| D | 60-77 |
| F | <60 |
| X | Unsatisfactory (student did not participate) |

**Lecture 1:**Measuring Stars with Light

**In this lesson**   we are going to study how light is used for observations of stars, star classifications into different types, and the physical differences between types of stars.

By the end of this lesson, the participants should be able to:

* Classify stars into spectral types;
* Describe the temperature and luminosity of the stars in a given classification;
* Describe the method of trigonometric parallax for measuring the distance to a star (or any other object);
* Construct a temperature luminosity (HR) diagram for stars;
* Explain the information contained in a temperature luminosity (HR) diagram;
* Use the Doppler effect to measure the velocity of a star moving towards or away from us.

Lesson Plan:

**Engage:** Ask the students to dialogue about different types of energy and how do we readily know sensorially it is a different type of energy

Ask the students about propagation of energy from sources in outerspace

While the dialogue is progressing the lecturer will make sure the following themes are brought to the subject: ( the way to do it is dialogical)

**Subjects to underline**

**a.Wave properties of light**

**b.Spectra**

**c.Radio waves to gamma waves**

**d. Black body radiation**

**e. magnitude,**

**f.stellar luminosity,**

**g. apparent brightness**

**h. intrinsic luminosity**

**i. parallax.**

**j. Brightness-Luminosity Relationship and Hurtzul-sprunger diagram**

**k. Inverse square law**

**l. Doppler effect**

**Evaluate ( individual) :**

* Students will make a report on the relationship between the temperature of an ideal radiator and the amount and type of electromagnetic radiation that it will emit;
* Identify the methods astronomers use to display and interpret the light from an astronomical object and explain how to interpret the various methods for displaying a spectrum of light from an object. (2 pages 1.5 spaces)

**Explore: Group Assessment**

* Students will break into groups to create a simple spectroscope
* **Evaluate:** At home the students will use it to observe/point ( I will give them safety orientation as not to use it directly to the sun, not to use it pointing at fire etc) different sources of light at home , the student will draw the spectra (or record the sound) and next class we will begin comparing their drawn spectra for different light sources and dialoguing about reasons for possible differences between the spectra from equal sources in the group.

**Lesson 2. Stellar Nurseries**

In this lesson we will be dialoguing on the birth of stars in nebulae and their solar systems. Gravitational collapse and proto- stars, and the dynamics of how hundreds of stars can form in a single nebula, and how most stars are in binary (or more) systems.

**At the end of the lesson the students should:**

* 1. List and describe the different steps in the formation of a star
  2. Recognize some of the structures seen in images of molecular clouds like the one in Orion

**Lesson Plan:**

**Engage:** a history about gravity … i.e. lets dialogue of all the things humans will be able to do if we would live on a planet with no gravity? ( 20 mins)

( teacher make transition to star formation)

* 1. How stars are born (protostars)
     + Role of Gravity
     + Star formation
     + Stellar nurseries
       - Formation of a planetary nebula How it happens?
       - Shapes of planetary nebulae
       - Cosmic Recycling
       - Massive stars
       - Binary systems: things that happen when a star is orbited by a second star in a binary system.
* **Explore:** We explained that massive stars have shorter lifetimes than low-mass stars. Even though massive stars have more fuel to burn, they use it up faster than low-mass stars. You can check and see whether this statement is true. The lifetime of a star is directly proportional to the amount of mass (fuel) it contains and inversely proportional to the rate at which it uses up that fuel (i.e., to its luminosity). Since the lifetime of the Sun is about 1010 y, we have the following relationship:  
  𝑇=1010𝑀𝐿yT=1010MLy where *T* is the lifetime of a main-sequence star, *M* is its mass measured in terms of the mass of the Sun, and *L* is its luminosity measured in terms of the Sun’s luminosity.
  1. Explain in words why this equation works.
  2. Use the data in table lecturer provided to calculate the ages of the main-sequence stars listed.
  3. Do low-mass stars have longer main-sequence lifetimes?
  4. Do you get the same answers as those in table lecturer provided?
  5. **Individual ASSESMENT ( at home to deliver next class)**
* Explain how and why massive stars evolve much more rapidly than lower-mass stars like our Sun
* Discuss the origin of the elements heavier than carbon within stars
* Go to the page which indexes all the publicly released Hubble Space Telescope images by subject: http://hubblesite.org/newscenter/archive/browse/image/. Under “Star,” go to “Protoplanetary Disk” and find a system—not mentioned in this chapter—that your like, and prepare a short report to the class about why you find it interesting. Then, under “Nebula,” go to “Emission” and find a region of star formation not mentioned in this chapter, and prepare a short report to the class about what you find interesting about it. ( reports to be presented in the next class and will last 3 minutes per student) I say 3 minutes approximately.

Assessment as **group work: unless the person tells about anxieties)**

1. Have your group make a list of the reasons why a star that formed at the very beginning of the universe (soon after the Big Bang) could not have a planet with astronomy students reading astronomy textbooks (even if the star has the same mass as that of our Sun).
   1. Are we allowed to discuss the list in the classroom? I need to know to finish this lesson ( after this if we are allowed to present and dialogue I will regroup). If we are allowed to discuss it then the groups will present their points.
2. Since we are pretty sure that when the Sun becomes a giant star, all life on Earth will be wiped out, does your group think that we should start making preparations of any kind? Let’s suppose that a political leader who fell asleep during large parts of his astronomy class suddenly hears about this problem from a large donor and appoints your group as a task force to make suggestions on how to prepare for the end of Earth. Make a list of arguments for why such a task force is not really necessary.
3. Many astronomers think that planetary nebulae are among the most attractive and interesting objects we can see in the Galaxy. In this lesson, the lecturer only showed you a few examples of these objects taken with the Hubble or large telescopes on the ground. Have members of your group search further for planetary nebula images online, and make a “top ten” list of your favorite ones (do not include more than three that were featured in this chapter.) Make a report (with images) for the whole class and explain why you found your top five especially interesting. (they have to check a figure I will provide. .)
4. You can estimate the age of the planetary nebula in image the lecturer provided. The diameter of the nebula is 600 times the diameter of our own solar system, or about 0.8 light-year. The gas is expanding away from the star at a rate of about 25 mi/s. Considering that distance = velocity ×× time, calculate how long ago the gas left the star if its speed has been constant the whole time. Make sure you use consistent units for time, speed, and distance.
5. If star A has a core temperature *T*, and star B has a core temperature 3*T*, how does the rate of fusion of star A compare to the rate of fusion of star B?

The report has to be delivered before or at the beginning of lesson3

**Lesson 3: Telescopes**

In this unit, will cover the basic kinds of telescopes and how they work, from all parts of the electromagnetic spectrum. We will discuss what sort of instrumental astronomers use to study stars, such as photometers and gamma-ray burst detectors. There will also possibly be a visit arranged to visit the vast collection of Harvard’s glass plates collection, which were the data collection technique used by Harvard Observatory astronomers a century ago to discover many of the basic properties of stars this course covers.

**At the end of this lesson the student should**:

Understand how telescopes work and how they can contribute to our knowledge of the universe

Understand and explain why we need more than one telescope

Students will describe why space-based telescopes are important

**Lesson Plan:**

**Engage:** link the lessons on light engaging the students to think on assuming the role of being the directors of a space agency: if you would be the director of a high income country space agency what tools will you create to generate new observations and new science?

Transition the dialogue to touch the following themes during its progress:

1. Types of telescopes: Radio, Reflecting, Refracting , tool used to observe from ultraviolet to Gamma
   1. How telescope gather and measure
   2. Challenges associated with the data acquired by telescopes
2. Factors that hinder astronomy observations from Earth
3. Power limitations
4. Observations from Outer-space
   1. i.e. xRay, gamma, radio,
   2. missions at the Harvard centre for Astrophysics
      1. Chandra (x ray centre) (Paul Green)
      2. LEDA ( Lincoln bring someone from LEDA)
5. telescopes used for exoplanet and finding live in outer-space:

**Individual Assessment:**

1. we discussed some of the ground and space based telescopes used to gather and analyse data by astronomers. Choose one telescope download a data set, display it: visually or auditorially or both and share with the class the following
   1. What kind of information may you extract from this data? and how?
   2. In what way can a telescope be considered to be a time machine? (Hint: Think about how far away the objects in the sky are.)
   3. How could you make your model telescope more effective or powerful?
   4. How might scientists use what they learn about the universe to help them build better and stronger telescopes and other instruments?
   5. Why space physics efforts are only directed to the further development of of high performance architectures such as multi-core CPUs, powerful graphic cards and interoperability? How will your telescope and data acqusition tools will facilitate more dynamic and detailed inspection of large data sets ?

Group assessment:

1. Today we begun the lesson by role playing. Now in teams lets get the teams to write a proposal for a new telescope: you have to describe: what kind of information the telescope it will receive. What kind of question about the Universe it will provide information about? How important is your team question for our understanding of the University and for the advancement of other endeavours ( i.e. humans beings, development of science or others) the team have to present your proposal as to convince a review board of investing money on your idea. To deliver 2 days after the class.

**Lesson 4- Why do Stars Shine?**

In this class we will cover what makes stars shine, and how stellar fusion occurs, and the elements created as a result of fusion. We will also cover stellar convection, and the layers that make up a star.

At the End of this Unit the students should:

1. Identify different causes of electromagnetic energy causing the emission of brightness.
2. The student will be able to track and explain each step of the trajectory of a photon emitted from the core of a star
3. Explain what is the role of protons in the process of fusion in the core of a star
4. Students will be able to build a simple photometer and measure the power of the sun

**Lesson Plan:**

Engage:

1.Have the students listening and seeing data on a solar emission:

* 1. Have the students explain why space scientist are so obsessed with brightness and what range of parameters scientists may extract from it? …i.e. what is brightness?

**Engage:** (In this lesson the students will begin listening to a magnetic fluctuation data from a coronal mass ejection from a star).

**Explore:** play the movie stellar collisions

1. Protons
2. Photons
3. Electrons
4. Fussion
5. Layers of an average star
   1. photons
   2. Core
   3. Radiative zone
   4. Transition zone
   5. Tachocline
   6. Corona
   7. Convective zone
   8. Photosphere
   9. Power spectra
   10. Bunsen photometer
   11. Nucleosynthesis for stars of different masses

Group Assessment: Determination of the Sun's power :

The students will break into groups and in groups will build a simple bunsen photometer that uses their cheeks and ears as detectors.

**Individual assesment**

1. Have the students dialoguing on the flow of those particles through our solar system until it arrives to earth and any natural phenomena that may have an effect on those particles. The student will calculate the intensity of a coronal mass ejection detected from Earth(in Decibels) and will compare that to the intensity of a coronal mass ejection detected from a constellation of satellites.
2. The student will calculate the power spectra of the coronal mass ejection using the sonoUno software. The student has to turn in the results in the next class. The report will include
   1. Local conditions of the satellite (position, magnetophesric effects
3. The students will use the bunsen photomet to calculate the power of the sun.
4. The students will use the bunsen photometer with other semitransparent materials found on daily life and using their cheeks/ears as a detectors. Students will record the measured power and will relate distances and how the energy flow per unit area through a surface change by semi transparency, reflection, trans- mission?

**Lesson 5: A Stellar Census**

At the end of this lesson the students will be able to relate the star energy output and mass to the star evolution . We will cover how stellar mass is important and determine a star’s life, the diversity of stars based on their sizes, and the Hertzprung-Russell diagram.

**At the end of this lesson the student:**

Will apply what we know about stars to derive a relationship of mass and velocity for the lifetime of a star.

Identify the different types of star clusters that stars inhabit;

Compare and contrast the HR diagrams for different types of star clusters;

Describe the process by which astronomers measure the distance and age of a star cluster

Lesson Plan:

**Engage:** have the students estimating the age or stage of life of different things we will mention and have them thinking about the margin of error in their approximations. (trees, rocks, estimating age or stage in the life of a star.

* 1. The lesson will begin refreshing the acquired knowledge on The Process of Star Formation

Nuclear Fusion in Protostars

Stellar Evolutionary Tracks in the HR Diagram

Failed Stars: Brown Dwarfs

Open Clusters

Globular clusters

Variable stars

Spectroscopic parallax

1. Estimation of age of a star using the relationship t≈M/Lt≈M/L ( I will explain this slowly not to lose anyone)
2. Create a Hertprung- Russel diagram with SDSS data http://cas.sdss.org/dr7/en/proj/advanced/hr/
3. Measure the age of a star cluster: during the review I will do a demonstration.

Individual Assessment:

1. The student will create an HR diagrams for an open cluster (the Pleiades) and a globular cluster (Palomar 5).
2. The student will take the data and create a detailed HR diagram for Palomar 5   
   the instructions for getting the data are http://cas.sdss.org/dr7/en/proj/advanced/hr/mast.asp : The instructions for getting the data are at http://cas.sdss.org/dr7/en/proj/advanced/hr/mast.asp (that is, the apparent magnitudes) for many stars in the Palomar 5 cluster using the Radial Search or SQL ( not accessible but working on it now, none of those astronomy resources are accessible) Search tools. Use one of these tools to collect data on a number of stars in Palomar the student will follow the instructions given in the Exercise 7 box to create an HR diagram for Palomar 5.
3. Answer Question Can you perceive the main sequence on this diagram? Can you identify any of the giants and super-giants? If so, identify these groups of stars on your diagram."
4. You should now have successfully created a real HR diagram (well actually, a "color”-magnitude diagram) for a real globular cluster using data from the Sloan Digital Sky Survey. Submit your report with a (paragraph or so) discussion of the lab and how well you think it illustrates some of the concepts we studied in Lessons 1 to 4.
5. Digital Quiz

**Lesson 6: Our Star, the Sun :**

The best studied star (by humans) in the universe we know is the Sun. We will cover the details we see on the sun (such as sunspots), and its layers from dense core to super-heated corona. We will also prepare for our observatory trip and observations in lesson 5.

**By the end of this lesson the student**

Learn about our sun by exploring various aspects of it, including its composition, interior workings, and relationship to the Earth.

1. Learn about our sun by exploring various aspects of it, including its composition, interior workings and relationship to the earth.
2. Extend the concepts of apparent magnitude, apparent distance and luminosity to recognize different luminosities and evolutionary stages from different stars.
3. Relate apparent luminosity and apparent distances to the evolution of the Sun
4. Have the students recognizing and calculate different luminosities from different Suns ( stars).
   1. We will be performing together an example during the flow of our **Expand** dialogue.
5. The student will interpret CELIAS , EIT data to approximate the velocity of the Solar wind.
   1. We will be performing together an example during the flow of our **Expand** dialogue.
6. The student will calculate the mass of a coronal mass ejection
   1. We will be performing together an example during the flow of our **Expand** dialogue.

**Lesson Plan:**

Prominences

Corona

Chromosphere

Chromosphere Corona

Suns Spots

Differential rotation

Solar Wind

Microgravity

Magnetometers

Solar Cycle

Earth magnetic field

**Individual Assesment:**

1. The student will go to the SOHO webpage and will search for days when the solar wind was quiet and days when SOHO detected solar flares and coronal mass ejections the student will select three days and will calculate the velocity and acceleration of a coronal mass ejection.

**Group Assesment:**

The students will use the sonoUno or anyother program of their preference to plot data from the solar cycle of the Sun. The students will relate given solar cycle periods to periods on earth the teams will search and find (i.e. periods of draught, periods of high precipitation etc and to the geometry of earth magnetic field).

The students will try to convince the government to invest money on possible ways to prepare for the next coronal mass ejection.

Students will submit their reports on \_\_\_\_\_\_\_\_\_\_ using the digital platform \_\_\_\_\_\_\_

Late submissions will not be accepted.

**Lesson 7** digital visit to the Clay Telescope:

**Engage**: This lesson will begin with a presentation from Dr. Belinda Wilkes astronomer at the Chandra xRay observatory at the center for astrophysics studying the death and evolution of the stars. She will talk about Chandra's mission, objectives, and future and also as part of this talk about its observations of the death of stars since X-ray emission is so key to study the evolution and death of stars. We want to highlight some of the missions and science being done at Harvard. Then we will do a transition to observe some binary systems using the clay telescope. This lesson will be planned later as I am exploring what the Clay telescope is capable of. Most likely I will have the students dividing in teams steering the telescope taking spectras of star clusters…and identifying the evolutionary stage of different ones. But we are exploring the capacity of the telescope)

**Home work**: for the next lesson read the article: Kalirai, J. “New Light on Our Sun’s Fate.” *Astronomy* (February 2014): 44. What will happen to stars like our Sun between the main sequence and the white dwarf stages.

**Lesson 8 Stellar Middle Age and Death**

In this unit we will cover how a star swells into a red supergiant near the end of its life. From here, we will then discuss how a star sheds its outer layers, leaving behind a planetary nebula with a white dwarf at its center. Alternately, we will discuss the small fraction of stars that end their lives in a supernova- the biggest explosions in the universe.

**By the end of this lesson the student should**

1. Explain why the difference in elements from stars of different masses and clusters at different stages.
2. Describe how the main-sequence turnoff of a cluster reveals its age
3. Identify and describe the events happening in stars of different masses when it exhaust the hydrogen

**Lesson:**

**Engage**: have the students comparing the life evolution of a human being with the stages of the evolution of a star.

**Expand**:

The lecturer will make sure of doing a transition to talk about:

Elements in open clusters

Elements in Globular clusters

Interior of a massive star right before its death

Death of low mass stars

**Explore: In groups unless anxieties are reported.**

1. Have your group take a look at the list of the brightest stars in the sky I provide What fraction of them are past the main-sequence phase of evolution? The text ( I provide) says that stars spend 90% of their lifetimes in the main-sequence phase of evolution. This suggests that if we have a fair (or representative) sample of stars, 90% of them should be main-sequence stars. Your group should brainstorm why 90% of the brightest stars are not in the main-sequence phase of evolution.
2. Reading an H–R diagram can be tricky. Suppose your group is given the H–R diagram of a star cluster. Stars above and to the right of the main sequence could be either red giants that had evolved away from the main sequence or very young stars that are still evolving toward the main sequence. Discuss how you would decide which they are.
3. The team will be able to identify at least one open cluster visible at this time of the year. Describe them in terms of the cluster evolution

**Evaluation:**

1. **Individual assessment ( to deliver before or at the beginning of next meeting)no late reports accepted.** 
   1. What is the first event that happens to that exhausts the hydrogen in its core and stops the generation of energy by the nuclear fusion of hydrogen to helium? Describe the sequence of events that the star undergoes.
2. Describe the evolution of a star with a mass similar to that of the Sun, from the protostar stage to the time it first becomes a red giant. Give the description in words and then sketch the evolution on an H–R diagram.
3. Describe the evolution of a star with of a star that is 20 times the mass of our sun similar from just after it first becomes a red giant to the time it exhausts the last type of fuel its core is capable of fusing.
4. Describe why lower surface temperature than the Sun and are more luminous. How do these stars produce so much more energy than the Sun?
5. Describe the two “recycling” mechanisms that are associated with stars (one during each star’s life and the other connecting generations of stars).

**Quizz ( questions for the quizz)**

1. A star does not change its mass very much during the course of its main-sequence lifetime. While it is on the main sequence, a star converts about 10% of the hydrogen initially present into helium (remember it’s only the core of the star that is hot enough for fusion). find out what percentage of the hydrogen mass involved in fusion is lost because it is converted to energy. By how much does the mass of the whole star change as a result of fusion? Were we correct to say that the mass of a star does not change significantly while it is on the main sequence?
2. massive stars have shorter lifetimes than low-mass stars. Even though massive stars have more fuel to burn, they use it up faster than low-mass stars. You can check and see whether this statement is true. The lifetime of a star is directly proportional to the amount of mass (fuel) it contains and inversely proportional to the rate at which it uses up that fuel (i.e., to its luminosity). Since the lifetime of the Sun is about 1010 y, we have the following relationship:

T=1010MLyT=1010MLy

where T is the lifetime of a main-sequence star, M is its mass measured in terms of the mass of the Sun, and L is its luminosity measured in terms of the Sun’s luminosity.

* 1. Explain in words why this equation works.
  2. Use the data ( I will provide it) to calculate the ages of the main-sequence stars listed.
  3. Do low-mass stars have longer main-sequence lifetimes?

**Lesson 9: Stellar Corpses**

When they die, a star will turn into one of these (either/or) - a white dwarf, a neutron star, or a black hole. We will discuss these three ”stellar corpses” including what determines the end result, and the unusual physics that can occur in these exotic objects. We will also discuss how these exotic stellar objects and their creation is responsible for mnay of the elements on the periodic table.

By the end of this lesson the student will:

Be able to explain why white dwarfs are hotter regardless of their small size.

Be able to identify the different cooling processes in a white dwarf

Be able to

Engage: Presentation by Dr. Yvette Cendes

Lesson:

**Explore:**

**Evaluation**

Quizz: this lesson will finish with a x where students will match the stellar corpse to the star producing it and other questions about the fate of massive stars, pulsars , neutron stars and supernovae.

Lesson 10 **The First Stars**

The first stars in the universe, called Population III stars, have not yet been discovered. In this class, we will discuss the Epoch of Reionization in the early universe and the special properties of the first stars, and why signatures from these first stars are so hard to find.

By the end of this lesson the student will be able to:

* 1. Explain why the epoch or reionization is key in understanding the history of our Universe.
  2. Identify different stages during the evolution of our known Universe before during and after reionization.
  3. Identify how the first galaxies were formed and mapped the history and evolution of our known universe given the elements.
  4. Identify the stages from protogalaxies to galaxies clusters and galaxy filaments.
  5. Relate redshift to the determine the age of a sample of object and relate that to how much since the light was produced.
  6. To identify in general form the instruments at the Centre for Astrophysics and other places to study the re-ionization time.

**Lesson Plan**

**Engage:**

Have the students beginning making a cup cake and dialoguing about how to avoid for the flour to create clumps.

**Then transition**

Cosmic Galactic background

Protogalaxies

Early stars

Middle ages

Early universe density fluctuations

Galaxy filaments

Dwarf galaxies

Quasars

Population III stars

**Explore**

**Evaluate:**

Group evaluation: the class will break into groups and I will provide Spectral Energy Distributions to each group.

What can we say is going on in a given physical system from its Spectral Energy Distribution (SED)?

May your team infer any characteristics of the disk from the features in the chart?

( in the classroom I will display auditorially and visually examples of the charts and will have a demostration)

**Lesson 11: Life and the Stars**

Thousands of extrasolar planets have been discovered orbiting stars, and astronomers now statistically believe that all stars in our Milky Way have planets. But what sort of effects do stars have on their planets? In this lecture we will cover stellar factors that can affect life, such as stellar flares. We will also discuss how living next to a star affect us on Earth. We will talk about Kepler and the role of the center for astrophysics in Kepler’s mission and the discoveries done.

**At the end of this lesson the student will be able to:**

Determine possible effects of events happening in outer space here on earth

Identify the relationship between the transit duration and the orbital period of a planet

Infer how solar wind data and cosmic ray data may help to determine planet habitability.

apply Kepler’s laws to construct explanations about planetary transits.

interpret light curve data to make inferences about an exoplanet’s orbital properties.

Be knowledgeable about the relationship of planet size and signal noise

**Engage:** have the students watching the movie stellar collisions ( 7 minutes)

Dialogue on the evolutions of stellar events and its effects on life on Earth.

Give a demonstration of transiting planets using the Orchestar. Students will see the data as the sound is acquired. The astronomy lab agreed to help with this.

The lecturer will do a transition and will make sure to mention the following themes during the dialog with the students:

**Lesson Plan**

Exoplanets

Kepplers law of planetary motion

Transit method

Light curve

Transit depth

Orbital period

Transit duration

Systems with multiple planets

**Evaluation: Quizz**

Study the time-series plot I provided of observations for a star with three orbiting planets along with the light curves for the individual planets . The y-axes represent brightness and the x-axes represent time. In Figure 2, “0” on the x-axis represents the midpoint of the transit.

Based on those figures and what you have learned about transiting planets, determine the relative orbital period, and thus the order, of the planets. Which planet is closest to the star? Farthest? In between? Label a diagram of the three-planet system with your conclusions.

Be sure to explain your reasoning or provide evidence to support your answers.

**Evaluation Individual**: **( report to be delivered at the beginning of the next session no late reports will be accepted):**

From the kepler data the lecturer provided:

1. Find at least one or two planets in each of these size categories:
   * Earth or smaller (0 to 1.25 times Earth size) [example: [Kepler-10b](http://kepler.nasa.gov/Mission/discoveries/kepler10b)]
   * Super-Earth (1.25 to 2 times Earth size) [example: [Kepler-11b](http://kepler.nasa.gov/Mission/discoveries/kepler11b)]
   * Mini-Neptune (2 to 4 times Earth size) [example: [Kepler-11c](http://kepler.nasa.gov/Mission/discoveries/kepler11c)]
   * Neptune (4-6 times Earth size) [example: [Kepler-4b](http://kepler.nasa.gov/Mission/discoveries/kepler4b)]
   * Jupiter (6-15 times Earth size) [example: [Kepler-6b](http://kepler.nasa.gov/Mission/discoveries/kepler6b)]
   * Super giant (more than 15 times Earth size) [example: [Kepler-13b](http://kepler.nasa.gov/Mission/discoveries/kepler13b)]  
       
     Are there any Super-Earths or Mini-Neptunes in our Solar System?

1. What is the relationship between depth of the transits in the light curve and the size of the planet?  
   * Advanced question: Is it a linear relationship?  
     (Transit depth = planet size times some constant?)
   * More advanced: Derive a mathematical relationship between transit depth and planet size, given that the drop in star brightness will depend directly on the area of light blocked by the planet. [See also: [Transit Tracks](https://www.nasa.gov/kepler/education/formal/transittracks) activity.]
2. What is the relationship between the transit duration (how long it takes to transit) and the orbital period of the planet? [Example: compare Kepler-24b and Kepler-22b]
3. On the Kepler table the lecturer provided find at least 3 stars each with at least one planet in its habitable zone. Habitable zone is the region around a star where the planet's distance from the star allows for liquid water, i.e. planet temperature between 0° and 100°C.  
   [Hint: the [NASA Exoplanet Archive](http://exoplanetarchive.ipac.caltech.edu/cgi-bin/TblView/nph-tblView?app=ExoTbls&config=cumulative&constraint=koi_disposition+like+%27C%25%27&constraint=koi_teq_str%20between%20180%20and%20310) can be used to help in this search. In those tables, you can specify a range of parameters to limit the listing by putting "between x and y" in the box at the top any given column. E.g. "between 0 and 100".]
4. What is the relationship between the size of a star and the size of its habitable zone?
5. The orbit inclination of a planet is the angle that the orbit is tilted with respect Earth's orbit (our viewing direction). In the Kepler Discoveries table, a planet whose orbit inclination is 90 is perfectly aligned with our viewing direction.  
     
   What is the relationship between a planet's orbital inclination and the duration of its transits. {Hint: find two planets with similar size star and orbital radius, but different inclinations.}