N3 Educator Tutorial for
Astronomy Anywhere:
Remote Observing and Image Analysis

Last Revision: 12/30/2021

Introduction

These activities are intended to introduce students to astronomical images and how to make simple measurements in them. They are organized into 5 sessions that scaffold knowledge and skills. After completing the activities, students will be equipped to continue on to more open-ended projects using astronomical images if they are so motivated.

The learning objectives identified for each session can be helpful for the students to make connections between the things they are familiar with in their daily lives and less familiar concepts in astronomy.

Each session contains alternate and extra resources that may be used to provide variety in learning modes and/or greater context for the astronomical topics that are encountered in the activities.

The activities provided often go into greater detail on each subject than is needed for the overall learning objectives. The 5 sessions of this guide could be done over 1-2 weeks depending on your class schedule and the level of depth you choose.

Sessions Overview:

1. Cosmic Perspective:
    a. Your cosmic address and the scale of the Universe.
    b. Requesting your own images from a robotic telescope
2. What are images?
    a. Eyes, cameras, and telescopes
3. Making Pretty Pictures
    a. Exploring digital images
    b. What is color?
    c. Construct color images
4. Light Detectives: Measuring the brightnesses of stars
5. Astronomy from Home: The change of brightness over time in different kinds of astronomical sources
    a. Exoplanets
    b. Pulsating Stars

c. Exploding Stars

Session 1: A Cosmic Perspective

Learning Objectives:

- The Universe is vast in both space and time.
- Scale models are needed to understand the different sizes of the realms of the Universe.
- The Universe is full of many kinds of objects: e.g. planets, stars, nebulae, clusters, galaxies, and galaxy clusters.
- You can request your own digital images of astronomical objects from robotic telescopes online.

Activities:

1. **Tour of the Universe** (Interactive Lecture) [60 minutes]
    a. introduce students to the concept of a Cosmic Address. Have them brainstorm what the different lines of a cosmic address would be to send a postcard across the Universe. Accept all answers. [5 minutes]
    b. Have students work in small groups to determine what the sizes of the different realms of the Universe (Sun, Solar System, Solar Neighborhood, Galaxy, Local Group, Local Supercluster, Universe) would be in a scale model where the Earth is the size of a grain of salt (0.1 mm in diameter). Encourage them to guess and not spend time trying to calculate or look up answers. After a brief time, collect their guesses and reveal the true sizes. The scale is ridiculous. It gives nobody any useful sense of how big things are as they are all well beyond common experience. [15 minutes]
    c. Have students consider a different type of scale model where we keep zooming out from one realm to the next using a space more familiar to us: a movie theater. As you present each realm, solicit guesses for common objects that would represent the size differences between the realms. Then reveal the answers by clicking on the gray boxes. [30 minutes]
        i. An alternate version of this activity can be done in a more hands-on way using your classroom and a variety of simple materials to use for size comparison. This version includes a teacher guide and student worksheet:
            1. Size & Scale of the Universe Teacher Guide (PDF)
            2. Size & Scale Glossary (PDF)
            3. Size & Scale PowerPoint Presentation (PPTX)
            4. Realms of the Universe Activity Worksheet (PDF)
            5. Room Size Conversion Calculator (XLSX)
    d. Finally, consider the scale of time in the Universe by way of a cosmic calendar that scales the history of the Universe into one 365-day year. [10 minutes]
2. **Requesting Images from a Robotic Telescope** [30 minutes]

a. Depending on the number of devices and students you can have them work individually or in groups to visit the Observing With NASA website. At the website they request images to be taken by the Micro-Observatory, a pair of small robotic telescopes.
b. A Video Tutorial is available on how to use the Micro-Observatory robotic telescopes. You can skip this if you'd rather lead your students through the process yourself.
c. Visit the Control Center for the Micro-Observatory telescopes to request images.
    i. You can read more about the different objects by clicking on their pictures. Clicking on the "Observe" button will take you to a page to select observation parameters. The page will give you advice on the best parameters to select for each object. If available, always select all 3 color filters for use in the following activities.
    ii. The images do not always turn out for a variety of reasons, so have students request a few images to increase the chances of getting good data.
    iii. The system will send links to the images via email once they are ready (usually after only one night of observing). If students do not have an email address, perhaps a school email address can be used. Or, maybe an email address can be created for the class.
    iv. If students want to see example images, there is an archive of images at the Micro-Observatory Image Directory. The images are in FITS format, which standard image viewers do not usually understand. See the first activity in Session 3 for a tutorial on using the JS9-4L viewer embedded on the Micro-Observatory website for viewing FITS images. But note, the Image Directory provides GIF previews of the images and using the JS9 viewer is not really needed until Session 3.

Additional Resources for Going Further:

The following videos give grand tours of the Universe similar to the lecture:

- The Known Universe: The Known Universe by AMNH
- Cosmic Voyage:
    - part 1: IMAX: Cosmic Voyage HD pt 1/3
    - part 2: IMAX: Cosmic Voyage HD pt 2/3
    - part 3: IMAX: Cosmic Voyage HD pt 3/3
- The Intro to the movie Contact (1997): The Intro To The Sci-Fi Movie Contact (1997)
- The End to the movie Men in Black (1997): Men In Black [1997] Finale

Stellarium is excellent free sky simulating software. There are versions for desktop, mobile devices, and web-based use. It will simulate the view of the sky from any place on Earth at any time (over a period of thousands of years). This software can be used to demonstrate the motions of the Sun, Moon, planets, stars, nebulae, and galaxies in the sky as the Earth rotates on its axis and orbits the Sun. This is useful for determining the times when it is possible to observe different astronomical objects. Note, that for best results it is usually better to observe objects with a telescope when they are highest in the sky. This is both because there is less atmospheric distortion and because the mechanical mounts that hold and drive telescopes are more efficient in those positions.

Session 2: What are Images?

Learning Objectives:

- Images are formed when light is brought to a focus.
- Both human eyes and cameras use lenses to focus light.
- The retina is the focal plane of a human eye and contains cells that are sensitive to light. Rod cells are sensitive to light across the visible spectrum. Three types of cone cells sense light in a more narrow range of wavelengths: red, green, and blue.
- In modern cameras the sensor at the focal plane is an array of material that can become electrically charged when light shines on it. The amount of charge at each picture element, or *pixel*, can then be recorded as a set of numbers: a digital image.
- Telescopes are just large digital cameras. Most scientific-grade telescopes use mirrors rather than lenses to bring light to a focus.
- The main purpose of a telescope is to gather as much light as possible.
- The secondary purpose of a telescope is to achieve greater angular resolution.

Activities:

1. **Pinhole Projector** - Follow Activity 3, Experiment 1 to create a pinhole projector and use it to view the image of a candle. A candle flame is effective because its shape is clearly not a circle.
    a. If you further choose to do Experiment 2 to measure the size of the Sun, be sure to warn against looking directly at the Sun as it's brightness (especially in ultraviolet) can cause permanent damage to retinal cells.
    b. The procedure can also be repeated in Experiment 3 for the Moon, but it will need to be a full Moon viewed from a dark location to produce enough brightness.
2. **Lecture** - Includes slides to explain the pinhole projector, reflection, refraction, eyes, cameras, telescopes, and digital images. [60 minutes]
3. **Eyes and Telescopes** - MicroObservatory Lesson comparing the specs of your eyes to those of telescopes. A worksheet-based lesson plan (Student Journal). For an extension to **Comparison 3** in this activity, set up a DSLR (Digital Single-Lens Reflex) camera, binoculars or a small telescope for viewing the dots so that students can see that it is able to distinguish between them at a distance farther than any of their eyes can. The distances that will be found can vary quite a bit depending on the optics of the device you are using, the amount of daylight present and several other factors. The main idea to convey is that a larger optical aperture produces better resolution. [50 minutes]

Additional Resources for Going Further:

There are simple “build-a-telescope” kits, such as these from Flinn Scientific or the Galileoscope

Telescopes: Crash Course Astronomy #6 - PBS Video Series. Note: the Crash Course Astronomy videos from PBS give mostly the same information presented in the lecture slides, but some students may prefer consuming that information in video format. The astronomer in the videos (Dr. Phil Plait) speaks very quickly. Some students may find it useful to pause and rewind the videos or to play them at a slower speed.

Session 3: Making Pretty Pictures

Learning Objectives:

- There are many ways to display data contained in a digital image. Understanding both the nature of the data and the display technology is key to viewing digital images.
- Color is a physiological response to different wavelengths of light. The experience of color varies across humans (and many animal species).
- Color images combine light from the broad bands of visible light seen by the cones of the human eye: Red, Green, and Blue. Every pixel of a color screen is subdivided into a red, green, and blue sub-pixel. The colors of the visible spectrum are reproduced by illuminating each subpixel (r,g,b) to different brightnesses.
- Color can reveal physical properties of an object like chemical composition and temperature.
- Astronomers observe wavelengths of light from the entire electromagnetic spectrum.
- Color can also be used to represent data that is not visible, especially light beyond the visible spectrum.

Activities:

1. **Viewing Digital Astronomical Images** - Video tutorial from MicroObservatory on how to open and view images using JS9. Note: the software isn't altering the data, it's just choosing options for how to display the data. (PDF version of the Tutorial). Use this to open the images you acquired from the MicroObservatory in Session 1. [30 minutes]
2. **Lecture** - These slides discuss how human eyes perceive color, how digital images reproduce color, and how astronomers create color images from telescopic observations across the electromagnetic spectrum. [30 minutes]
3. **Create a Color Image**: This video tutorial or PDF Version leads students through the process of creating their own color composite images using their MicroObservatory Images and the JS9-4L image tool. [40-50 minutes]
    a. If time allows, some students may benefit from using this tool in an exploratory way, without instruction, prior to the lecture on color. Free-form exploration of this kind can help students formulate questions and motivation for the more purposeful activity.

Additional Resources for Going Further:

Go through the online tutorial about how to download data from the WISE mission:
http://wise.ssl.berkeley.edu/edu_accessing_images.html
Use the Creating Color Images tutorial to learn how to make a pretty picture:
http://wise.ssl.berkeley.edu/edu_making_color.html
Some of the software on this page is out of date or may not work well on your computer.
Here are some newer software tools:

- Web-based Image J
- JS9-4L image tool

Reading through the WISE tutorial will still be helpful and can give you pointers for using more advanced software like Photoshop or GIMP.

Additional archival data from IRSA (CalTech) and MAST (STScI) can also be used to make color images.

MicroObservatory occasionally hosts challenges to create and submit astro photos.

Session 4: Light Detectives: Measuring the brightnesses of stars

Learning Objectives:

- Brightness of a star is a measure of the amount of energy from the stars passing through a surface within a period of time.
- In a digital image we can infer the brightness of a star based on how much charge was recorded at each pixel that forms the image of the star over the duration of the exposure.
- Astronomers quantify color as the ratio of brightness at different wavelengths of light (this definition works for invisible light as well as visible light).
- Color can be used to differentiate different types of objects in an astronomical image.

Activities:

1. **Cookie Cutter Photometry**: a hands-on activity to demonstrate how brightness is measured in a digital image (photometry). The concept of background noise is introduced and how it is accounted for is also demonstrated. [60 minutes]
    a. Model magic can be substituted for Play-Doh in the activity.
    b. The concept of models could be discussed before doing the activity to prime the students to understand that the activity is a stand-in for the real concept. Having students point out the inadequacies of the model is both compelling and instructive.
    c. Do not attempt to smooth out the surface of the “clay,” as a naturally bumpy surface is a better model for the random fluctuations of the background noise in a digital image.
2. **Light Detectives** (student guide): Uses JS9-4L and image data from NASA’s WISE mission to measure the colors of sources in two fields of view. Students use the colors to

find a brown dwarf in the first image set and an ultra-luminous infrared galaxy in the second set. [50 minutes]

a. Slide Set - to lead students through the activity. It contains examples of the graphs that students will produce. The speaker notes contain background information for the instructor.
b. Teacher's Guide - contains additional information for the instructor, including answers to the questions at the end of each activity.
c. Data Table - A link to this Google sheet is in the student guide, in step 9. There are tabs in the sheet for the Brown Dwarfs and the ULIRGs including plots that will automatically fill in as the measurements are recorded in the data tables.
d. Repeating the measurements over and over again can become tedious for students. One method to abate this is to split up the stars and have students work on different subgroups of stars. Students can then record their measurements into a data table for the whole class.
e. Students can also benefit from working in groups on their measurements.
f. In a real research project, astronomers would not make these measurements "by hand." They would write computer code to automate the process and do it for every star in the image. This makes the measurements more consistent and much faster. Depending on the knowledge of the students, an extension activity could be done to have students sketch out a program to automate the measurements. For students with no knowledge of programming, you could have students write the program in English, describing the steps that it would need to do.

Additional Resources for Going Further:

Brown dwarfs: Crash Course Astronomy #28 - PBS Video Series
Galaxies, Part 2: Crash Course Astronomy #39 - PBS Video Series

Session 5: Astronomy from Home

Learning Objectives:

- Variable objects change their brightness over time for many reasons.
- We can measure variability by measuring the brightness of an astronomical object at different times.
- If we have observations of an object at many different times and make a measurement of its brightness at each time, we can construct a plot of brightness with time, this is known as a light curve.
- The manner in which an object is variable can often be differentiated by the details of its light curve.

Activities:

1. **Lecture Slides**: background information on the astronomy topics in this session.

    a. The websites for each activity also provide this information, but the slides are provided for instructors who wish to deliver this information via lecture.
    b. Videos that discuss these topics are also suggested in the Additional Resources section below.
    c. To avoid long lectures, the slides may split up to introduce the topic of each activity:
        i. Exoplanets: Slides 3-21 [30 min]
        ii. Cepheid Variables: Slides 22-26 [10 min]
        iii. Supernovae: Slides 27-36 [30 min]
2. **Exoplanet Finder Game**: students test their ability to recognize the shape of a light curve caused by a transiting exoplanet compared to other sources of stellar variability. [15 min]
    a. Some students may benefit from starting with this game (prior to instruction), as it can engage their curiosity about the subject. Students can return to the game after instruction to see if they can improve their scores.
    b. A hands-on alternative for starting Session 5 would be the “Detecting Planet Transits” activity listed in the Additional Resources section below.
3. **JS9 Exoplanet Activity**: students use the JS9 image processor embedded in the webpages to measure the changing brightness of a star known to have orbiting exoplanets observed by the GORT observatory. [20-30 min]
    a. Instructors may find it helpful to have students work in groups.
    b. Once students get the hang of making the measurements they can click “Complete Chart” and the system will show measurements of that star made by professional astronomers (or more precisely made by the computer programs created by professional astronomers).
    c. Students may find it fun to see how closely they can match these measurements. You could make a game of it by awarding points for how closely students match the professional measurements.
4. **JS9 Cepheid Activity**: students use the JS9 image processor embedded in the webpages to measure the changing brightness of a Cepheid Variable star observed by the GORT observatory. [20 min]
    a. Instructors may find it helpful to have students work in groups.
    b. Once students get the hang of making the measurements they can click “Complete Chart” and the system will show measurements of that star made by professional astronomers (or more precisely made by the computer programs created by professional astronomers).
    c. Students may find it fun to see how closely they can match these measurements. You could make a game of it by awarding points for how closely students match the professional measurements.
5. **JS9 Supernova Activity**: students use the JS9 image processor embedded in the webpages to measure the changing brightness of a supernova observed by the GORT observatory. After measuring the light curve, a second activity has students locate a line in the spectrum of several supernovae (along with the peak brightness). These two

measurements (of distance and cosmological redshift) are then used to determine the expansion rate of the Universe and therefore its age. [20 min]

a. Instructors may find it helpful to have students work in groups.
b. Once students get the hang of making the measurements they can click "Complete Chart" and the system will show measurements of that star made by professional astronomers (or more precisely made by the computer programs created by professional astronomers).
c. Students may find it fun to see how closely they can match these measurements. You could make a game of it by awarding points for how closely students match the professional measurements.

Additional Resources for Going Further:

Hands-On Activities:

★ Detecting Planet Transits: students model observations of planetary transits by standing in a circle with a model star (light bulb) in the center, and observing, through rolled up paper viewing tubes, a "bead" planet orbiting the star.
★ Parallax: students measure the parallax angle of a photograph of a star from several distances and determine the mathematical relationship between parallax angle and distance.
★ The Inverse-Square Law for Light: students measure the brightness of a light source at several distances and determine that the intensity of light (brightness) decreased with the distance squared.

Videos:

★ Hubblecast 116: Henrietta Leavitt
★ The Story of Subrahmanyan Chandrasekhar
★ The accelerating Universe with Alex Filippenko
★ Exoplanets: Crash Course Astronomy #27 - PBS Video Series
★ Binary and Multiple Stars: Crash Course Astronomy #34 - PBS Video Series
★ The Big Bang, cosmology part 1: Crash Course Astronomy #42 - PBS Video Series
★ Dark Energy, cosmology part 2: Crash Course Astronomy #43 - PBS Video Series