



# MicroObservatory Computer Activities

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# Introduction to MicroObservatory

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## **Overview of MicroObservatory**

MicroObservatory is a network of automated telescopes - located in Cambridge, MA and Amado, AZ - that can be controlled over the Internet. Users of MicroObservatory are responsible for taking their own images by pointing and focusing the telescopes, selecting exposure times, filters, and other parameters. The educational value lies not just in the image returned by the telescope, but in the satisfaction and practical understanding that comes from mastering a powerful scientific tool. Observations can be set up in advance and run automatically. Youth are actively involved in posing questions, designing investigations, gathering evidence, and interpreting their own results as they explore the universe. Youth and after-school instructors control the MicroObservatory telescopes over the Internet, from the convenience of their computer labs. Youth reserve telescope time, check weather, choose targets, select exposure times, color filters and other parameters. The system is completely automated; there is no human intervention in the loop: you and your after-school group are in charge!

## **MicroObservatory Guest Portal**

One of the easiest ways to take images with the MicroObservatory telescopes is through the Guest Observer Portal (GOP). All of the following activities can be completed using the GOP with some modifications. Approaching the activities this way removes the need to apply and enroll as a Guest Observer. It also makes the process of taking images very straightforward allowing the focus of the activity to be on the images and image processing. The drawbacks are (1) not being able to experiment with exposure times for the images and (2) having limited use of filters.

## **Enrolling Participants in MicroObservatory**

It is much easier if participants are enrolled in MicroObservatory prior to beginning the program. You can enroll participants as they register for the program or you can do them all at once as soon as your enrollment is complete.

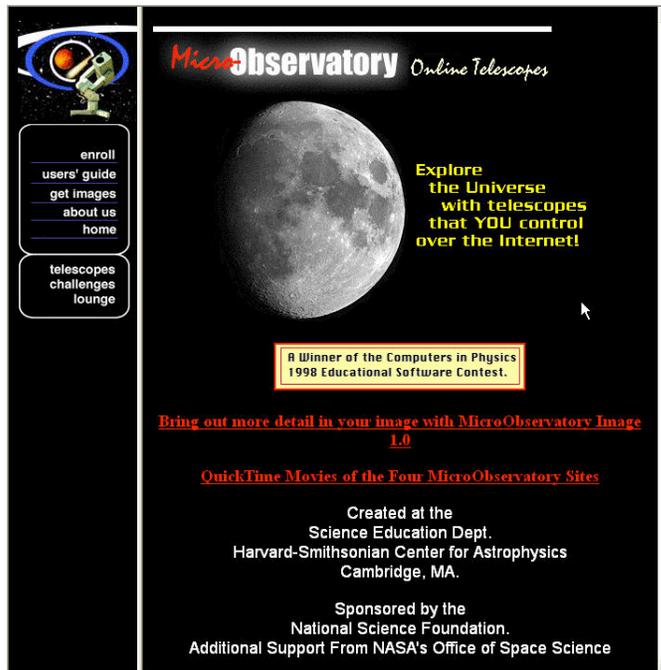
By pre-enrolling the youth, you can test their Guest Accounts by actually logging in prior to the start of this exercise. This will significantly reduce the frustration levels of those who do not have a lot of experience using computers.

The information needed to complete the enrollment process for each participant is:

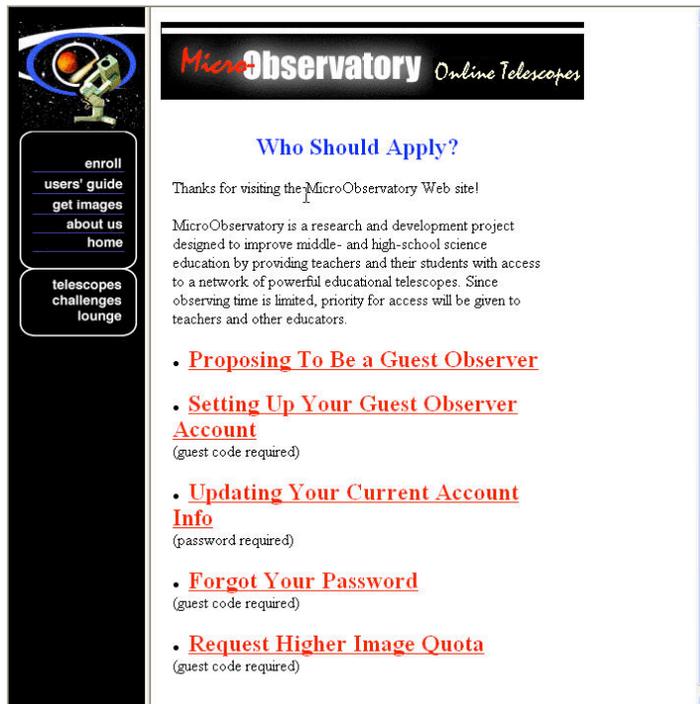
- First Name
- Last Name
- Street Address (Optional)
- Town
- State
- ZipCode
- Country
- Phone Number (optional)
- Email Address (students may use their sponsoring teacher's email address)
- School / Institution
- Profession (if applicable)
- Age
- Gender
- Grade
- Computer Experience: Novice, Intermediate, Advanced
- Username
- Password

Additionally you will be asked about the browser and operating systems in use at your computer lab. Be sure to record the participants' usernames and passwords in a safe place.

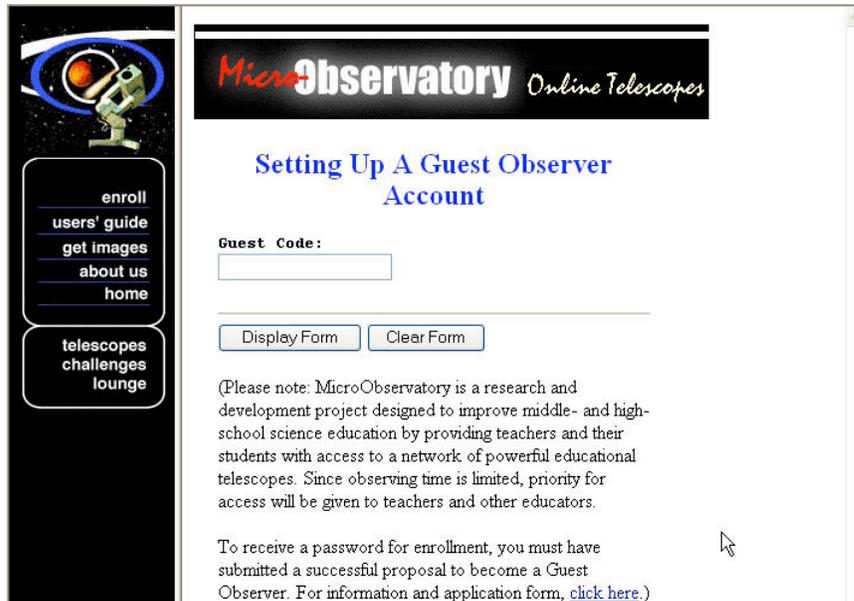
- Obtain your guest access code from the staff at MicroObservatory.
- Start from the MicroObservatory main page:  
<http://mo-www.harvard.edu/MicroObservatory/index.html>



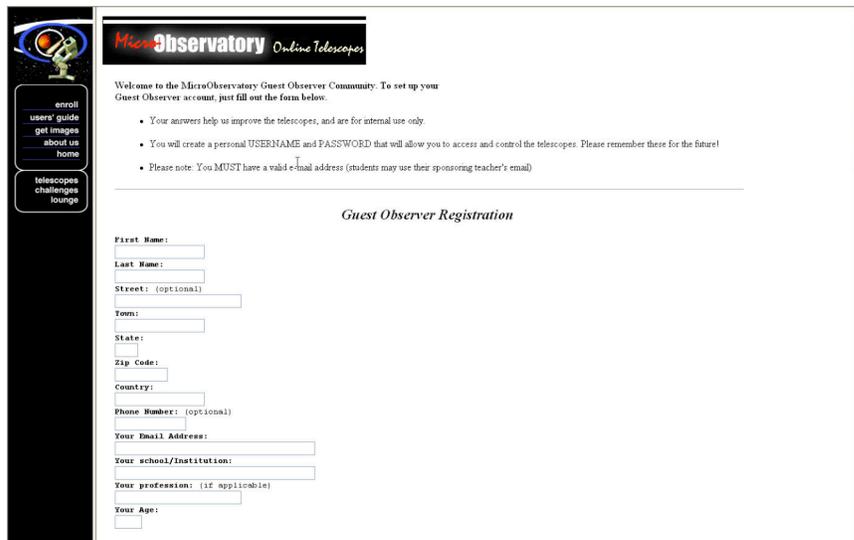
- ❑ Click **enroll** at the top of the navigation frame on the left side of the screen.



- ❑ At the Who Should Apply? Screen, click **Setting Up Your Guest Observer Account**.



- ❑ Enter your **guest code** in the text box. Click the **Display Form Button**.



- ❑ Complete the information for each participant. In assigning passwords for the youth, make sure that it is something that they can remember. The password can be changed if they forget.
- ❑ When all the information for the participant has been entered, click the **Register** button.

Repeat these steps for each person in the program.

# **Taking Images with MicroObservatory**

## Background

You are about to use a telescope that can detect objects far beyond our own galaxy... objects so distant that their light has been hurtling through space since before the first life emerged on land, nearly a billion years ago.

This telescope will do no more and no less than what you command it to do. Learn how to use it properly, and it will take you on a great adventure out in space and back in time, across our galaxy and far beyond. Go out and look at the sky on a clear, dark night. No machine can replace your own eye... or your mind's eye. Get to know the constellations, when they rise and set, how they change with the seasons. They will be your road map as you navigate the universe. Find good star charts. Read about the sky and learn which celestial events are headed your way. Try the challenges and puzzles that we will provide from time to time.

Above all, let your own curiosity and wonder be your guide. Get to know the mysteries of the universe that others, like you, are trying to solve.

## Enrollment

You must be enrolled in order to control the telescopes. Enrollment is free, but is currently by invitation only. Even if you are not enrolled, you can explore all parts of MicroObservatory, including the latest images that users have taken, along with challenges and puzzles.

## Web Browser & Internet Service

You will need Internet Explorer, Firefox, Safari, or a similar web browser that supports "frames" (multiple windows). Your browser's window should be opened to its full width. To get more viewing area, some browsers allow you to hide or shrink the control buttons at the top. You will also need to be able to access the Internet.

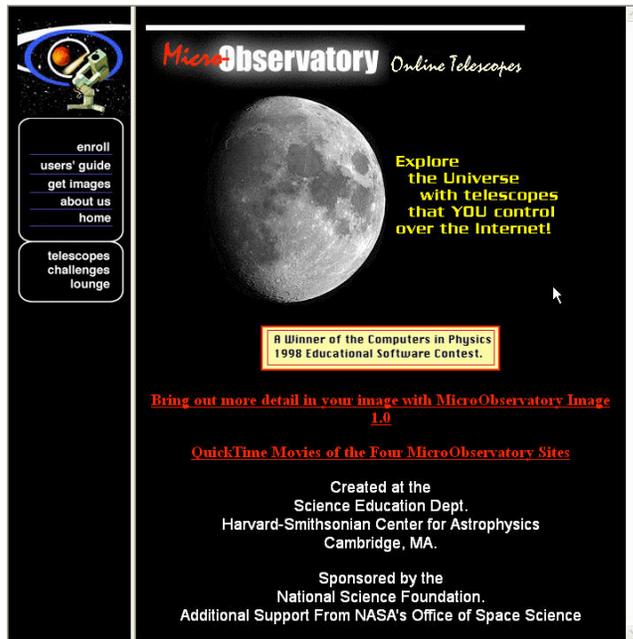
## Software

You don't need special software to view images from the telescopes. HOWEVER, in order to get the most out of your images, it helps to have IMAGE PROCESSING software that lets you adjust the brightness, contrast, or background noise in your images. The telescopes can also return images in the FITS format, which contains more information, than GIF format. To view or process images in FITS format, you will need special software.

## Accessing the MicroObservatory Home Page

Start from the MicroObservatory main page:

<http://mo-www.harvard.edu/MicroObservatory>



## Selecting a Telescope

Click on **telescopes**. The select telescope site window appears.



You should check the weather at a telescope's location before you use the telescope. Check the weather and forecast at a particular telescope site by **clicking the city** in which the telescope is located. The telescopes should only be used under clear skies.



Click **select 'scope** to return to the Select Telescope screen.

Check the availability of time slots for the telescope. Click on the **entries** for a telescope.



The number of images already scheduled for a particular telescope is displayed.

**Image Request Queue**

**Telescope: Cecilia**

**Location: Tucson, AZ USA**

**Queue: 95 entries**

Observer	Object	Reference Number	Time
• baconbits	Moon	baconbits-03/10-12:55:20	ASAP
mcrae19	Perseus	mcrae19-03/10-09:34:43	6:00 PM
mcrae19	Perseus	mcrae19-03/10-09:40:03	6:03 PM
mcrae19	Perseus	mcrae19-03/10-09:41:23	6:09 PM
mcrae19	Perseus	mcrae19-03/10-09:43:08	6:12 PM
mcrae19	Perseus	mcrae19-03/10-09:43:42	6:15 PM
mcrae19	Perseus	mcrae19-03/10-09:44:26	6:18 PM
baconbits	comet TREVOR	baconbits-03/10-12:52:36	6:42 PM
ffs	Mercury	ffs-03/10-08:55:20	6:51 PM
ffs	Mercury	ffs-03/10-08:55:01	6:54 PM
ffs	Mercury	ffs-03/10-08:54:44	6:57 PM
mcrae44	canismajor3	mcrae44-03/10-12:57:25	7:00 PM
cquestions	Andromeda Galaxy M31	cquestions-03/09-11:00:11c	7:30 PM
cquestions	Andromeda Galaxy M31	cquestions-03/10-11:00:13c	7:30 PM
moguest	NGC 598 M33	moguest-03/10-12:15:53g	7:30 PM
cquestions	Orion Nebula M42	cquestions-03/10-11:00:14c	7:33 PM
moguest	NGC 891	moguest-03/10-12:15:54g	7:33 PM
mcrae24	taurus	mcrae24-03/10-09:32:06	7:45 PM
aanders	egeria	aanders-03/10-10:54:47	8:00 PM
aanders	egeria	aanders-03/10-10:55:06	8:03 PM
mcrae39	cassiopeia	mcrae39-03/10-13:02:11	8:06 PM
baconbits	comet TREVOR	baconbits-03/10-12:50:39	8:18 PM
baconbits	comet TREVOR	baconbits-03/10-12:51:14	8:21 PM

From this screen you can determine who has requested images, the celestial objects are being photographed, and the time when the pictures are scheduled to be taken. You should scroll through the list of images to determine free times.

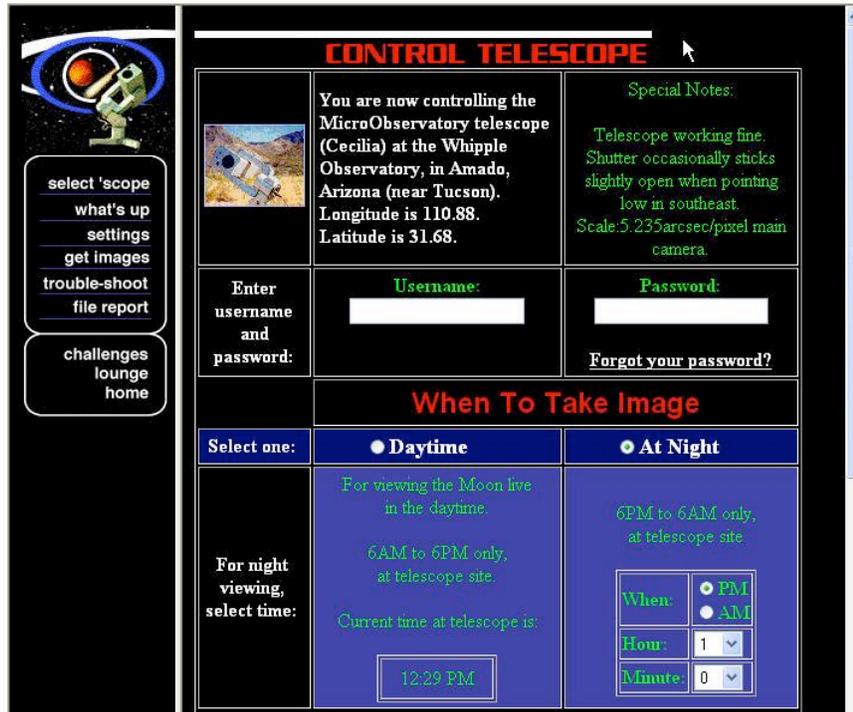
**Images can be scheduled 3 minutes apart.**

Once you have determined that skies are clear at the desired location and you know when there are free times for your telescope, click **select 'scope** to return to the Select Telescope screen.

Select a telescope on the world map. To select the telescope that you want to control click on one of the red dots.

You enter the Control Telescope site. Keep in mind that the process that follows is the same independently of the telescope you choose.

## Controlling a Telescope



CONTROL TELESCOPE		
	You are now controlling the MicroObservatory telescope (Cecilia) at the Whipple Observatory, in Amado, Arizona (near Tucson). Longitude is 110.88. Latitude is 31.68.	<b>Special Notes:</b> Telescope working fine. Shutter occasionally sticks slightly open when pointing low in southeast. Scale: 5.235 arcsec/pixel main camera.
Enter username and password:	Username: <input type="text"/>	Password: <input type="password"/>
	<a href="#">Forgot your password?</a>	
<b>When To Take Image</b>		
Select one:	<input checked="" type="radio"/> Daytime	<input type="radio"/> At Night
For night viewing, select time:	For viewing the Moon live in the daytime. 6AM to 6PM only, at telescope site. Current time at telescope is: <input type="text" value="12:29 PM"/>	6PM to 6AM only, at telescope site  When: <input checked="" type="radio"/> PM <input type="radio"/> AM Hour: <input type="text" value="1"/> Minute: <input type="text" value="0"/>

Enter username and password. The username and password for each participant is determined when the participant registers on line.

### When to take an image

You'll need to know WHEN the object you want is above the horizon and HIGH ENOUGH for you to take a clear image. (Usually, the higher in the sky it is, the clearer the image, because the telescope has to look through less atmosphere). You can use astronomy magazines, other Web sites, or the information in this site to help you figure out "what's up when."

### Daytime

During the daytime (6 AM to 6 PM at the telescope's location), you can use the telescope "live". This is ideal for observing the Moon from your classroom, when it is up during the daytime. Some planets are also observable during the day! Sorry, the telescope cannot take images of the Sun.

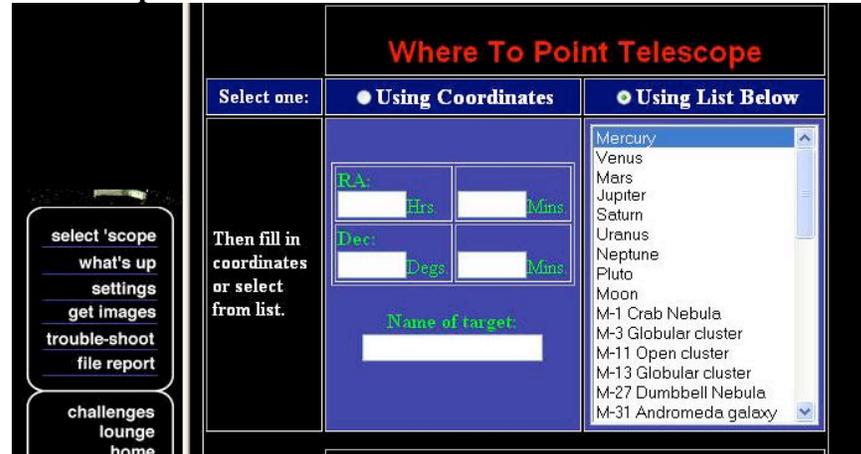
### At Night

To take an image at night, you must set the telescope controls in advance; the telescope will automatically take the image at the time you specify (between 6 PM and 6 AM at the telescope's

location). Don't forget to enter AM or PM and then the hour and minute desired.

Enter the time when you would like to take an image. To have the telescope to take an image at night (between 6 PM and 6 AM), select AM or PM. If the time slot is already taken, the telescope will let you and the participants know right after you try to take a picture.

### Point the telescope



You can point the telescope in two different ways. Be sure to select the appropriate button:

Enter the coordinate of the objects

Use the list of objects whose coordinate the telescope already knows. pull-down

### Using Coordinates

You can enter the COORDINATES of the desired object. These coordinates, called "Right Ascension" (RA) and "Declination" (Dec) are like a Zip Code that tells the location of an object on the sky. You'll want to use these coordinates for distant objects such as stars and galaxies. You can find an object's coordinates from star charts and catalogs available in books, magazines, on the Web, or elsewhere on this site. (The telescope's computer automatically takes into account the rotation of the Earth when it points the telescope.)

### Using List Below

Use the convenient list for viewing the Moon and planets. Objects that are inside our Solar System (such as the Moon, planets, and asteroids) appear to move against the "fixed" background of distant stars, and their coordinates change with time. The MicroObservatory computer will automatically calculate the

position of the object at the desired time and point the telescope for you. The list also contains other popular objects for viewing. Note: The Information returned with your image lists the actual coordinates (RA and Dec) used.

### Controlling Camera Settings

home

### Camera Settings

Select one:  Finder Camera  Main Camera

Then set exposure time and filter:

Exposure: [input] secs. Filter: Clear [dropdown]

Exposure: [input] secs. Filter: Clear [dropdown]

Zoom In is NOT Recommended

Zoom In  Zoom Out

Default Focus  Manual Focus: [input] (0 to 2800)

Take Picture Clear Form

F.S.D./R.G.

#### Finder Camera

The Finder Camera has a 10-degree field of view (about half the size of the constellation Orion). Use the FINDER for observing constellations, comet tails, and other objects that spread across the sky. Normally you will be using the telescope’s main camera.

#### Main Camera

The MAIN CAMERA is used for most work. Its 1-degree field of view comfortably includes the Moon, planets with their moons, and all galaxies and nebulae except the Andromeda galaxy, M31. You will normally use the telescope’s main camera. Remind the participants to always use the main camera unless you tell them differently.

#### Exposure time

The MicroObservatory telescope’s light-sensing camera has a shutter that can remain open anywhere from 0.05 seconds to 60 seconds when you take an image. The time the shutter stays open is called “exposure time.” The longer the exposure time, the more light that the telescope can gather to make an image. The recommended exposure time for various targets is:

<b>Object</b>	<b>Time of day</b>	<b>Select target with...</b>	<b>Exposure Time</b>	<b>Filter</b>
<b>Moon</b>	Day or Night	Pull-down Menu	0.1 - .05 sec	Gray (Neutral Density Filter)
<b>Planets</b>	Night	Pull-down Menu	0.1 – 2.0 sec	Clear (No Filter)
<b>Stars</b>	Night	Coordinates	0.1 – 10 sec	Clear (No Filter)
<b>Star clusters</b>	Night	Pull-down Menu or Coordinates	5 – 30 sec	Clear (No Filter)
<b>Nebulae</b>	Night	Pull-down Menu or Coordinates	45 – 60 sec	Clear (No Filter)
<b>Galaxies</b>	Night	Pull-down Menu or Coordinates	45 – 60 sec	Clear (No Filter)
<b>Asteroids / Comets</b>	Night	Coordinates	15 – 60 sec	Clear (No Filter)

### **Filter**

A filter is a device that prevents some of the light from the celestial source to reach the light-sensing camera.

The default selection is “clear filter” which is no filter at all.

For very bright objects such as the Moon, you must use a grey filter (called a “neutral density” filter) to prevent the camera from being “inundated” with light. The grey filter reduces the light that reaches the camera by a factor of 10,000.

There are other filters: red, green, blue and IR filters. They all reduce the amount of light that reaches the camera.

### **Zoom In / Zoom Out**

Select “zoom out.”

Normally you should use “zoom out,” which is the default setting. Use “zoom in” only when trying to image a very small object such as the rings of Saturn.

Be warned that the “zoom in” will not return a larger image. Instead it will return only the central part of the image you would get with the “zoom out” setting.

### **Focus**

Ignore the focus command. The telescope focuses automatically. The default focus always produces the sharpest image. Manual focusing is only used for specialized experiments that require the telescope to be unfocused.

### **Taking the Picture**

Click the Take Picture button when ready. Before selecting this button make sure you enter all the required information. When you click on “take picture” the server tells the telescope to take an

image (of the Moon in this case) at the time you selected. A screen will automatically appear to confirm your request. If you have forgotten any required information, the screen will prompt you to re-enter it.

**Note:** on some browsers you will have to re-enter all the information again, or at least username and password. Remind the participants to take their time when entering their request; it will save time in the long run.

### **Take another image**

After successfully taking the first image you can click on select 'scope at the top of the menu on the left to go back to the Control Telescope page and take additional pictures of the object you initially selected or of another celestial object. You might want to try changing the time when to take the picture or the exposure time. It is a good practice to always take 2-3 pictures of the same object with the same choice of parameters to make sure to get at least a good shot.

### **Getting your image**

The telescope will take the image at the time you requested or as soon thereafter as the traffic permits. It takes from one to several minutes to take an image. This includes the time to point the telescope, take the exposure, and download the image over the Internet to the MicroObservatory server in Cambridge, MA.

The telescope will automatically send you an email when your image has been taken. If your mail-server alerts you to incoming mail only at long intervals, you may find it faster to simply check the QUEUE for the telescope on the SELECT TELESCOPE page in the CONTROL CENTER. The QUEUE lists all images still waiting to be taken.

When your image has been taken, it will be listed in the MicroObservatory IMAGE DIRECTORY. You can access this DIRECTORY from many parts of the website by clicking the button GET IMAGES.

Images are listed in the order they were taken, with the most recent image at the top. If you prefer, you can RE-SORT this directory to list images alphabetically by USERNAME. Just click on the column heading, USERNAME. That way, all your images will be grouped together.

### **Viewing your image**

Just click on the filename and the image will appear on screen, in GIF format. If you are viewing a SERIES OF IMAGES, you may wish to view just a THUMBNAIL image for each. (This saves on the download time.) Simply click on INFO, to the right of the Filename for your image. You can keep scanning through your thumbnail images, using the arrows at top.

### **Viewing images in FITS format**

The telescope takes images in FITS format, which contains more visual information than the GIF format used on the Web. The computer then converts the image to GIF format, and saves the image in both the GIF and FITS formats. The original FITS image is useful for advanced image processing, for measuring the brightness of objects, and for viewing fine detail. To retrieve a FITS image, first examine the GIF image by clicking on the Filename. Then Click on the "Save FITS image" link at the top of the image. The browser will save the FITS image. You will need special software to view or process this image. See SOFTWARE, below.

### **Information about your image**

The telescope records a great deal of useful information about how each image was taken. To view this information, click on INFO, to the right of the Filename for your image.

### **Saving (Downloading) FITS files**

You should set up a folder for your images on your computer or network. The directions for saving files using common computer systems and Internet browsers are:

#### **Macintosh - Internet Explorer**

Select "Download Link to Disk"

#### **Macintosh - Safari**

Control-Click

Select "Save this Link as..."

Make sure to choose Source as the Format when saving the file.

#### **PC (Windows) - Internet Explorer**

Click on filename underlined in blue that says "Save/Download."

### **Deleting an image**

Images will be saved in the IMAGE DIRECTORY for one week and then deleted.

# Processing Your Image

There is a lot more information in a typical image than meets the eye. To bring out the fine details, you must PROCESS YOUR IMAGE. Following is a brief description of the kinds of processing that may be useful in your experiments. During the course of this program you will learn how to process your images using the image processing software MicroObservatory Image 2.0. The software is available for free and can be downloaded from <http://mo-www.harvard.edu/MicroObservatory/>.

## Adjusting Contrast And Brightness

This is the simplest processing you can do. It is very useful for faint and low-contrast objects like galaxies or nebula.

## Background Specks

Some (or many) of the little white dots in your image are NOT stars: If they are a single pixel ("picture element") wide, they are likely to be background noise, called "hot pixels". This noise comes from the light-sensing electronic chip itself and is caused by heat, cosmic rays and other factors. You can eliminate this in programs like Adobe Photoshop that allow you to remove "dust" from photographs.

## Background Noise

If you use the opaque filter and try to take a picture, you will NOT get a completely black image. That's because the telescope's light-sensing chip itself produces electronic "noise" that is interpreted as faint light. By SUBTRACTING OUT this noise from your image, you can bring out faint details. To do this, you need to use an image-processing program (such as MicroObservatory Image 2.0) that allows you to subtract one image from another, that is, to subtract the "dark field" image taken with an opaque filter from the image you want to enhance. (Both images must have been taken with the same exposure time.)

There are typical image problems that participants will almost certainly encounter when using the MicroObservatory telescope. Make sure to address these problems early on to prevent participants from growing frustrated if unable to get a "good picture." Typical image problems are:

### **Image blank**



Exposure was too short. Opaque filter accidentally used. Overexposed (image is completely black on web, but white in MicroObservatory Image 2.0)

### **Image flaring**



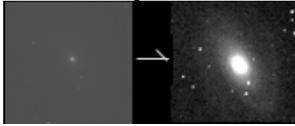
There was too much light. Cut down exposure, or for bright stars in a field, ignore. Most images of the planets show a bright vertical line, stretching top to bottom. There usually is a thicker ball of light in the middle of this vertical line. That's where the planet is located. The reason is that planets, being close and big objects, reflect a lot of light from the Sun. They are very bright, much brighter than the fainter and further galaxies, nebulae and many stars. The digital detector cannot record all that light in one spot, so it 'spills over' to the next part of the detector. Just like a bucket collecting water, if it gets too full, it spills the extra over the bucket's lip. Think of the detector as a large mosaic of water buckets that catch and record light. If there's too much light in one bucket, it spills into the next one above and below it. (Note: spillage does not happen on each side!) To prevent this light 'spillage', use shorter exposure times. You might also need to use the grey filter, like you do when imaging the Moon. That filter blocks much of the bright light from the object.

### **Blurry Image**



An image can be blurry for several reasons. If you changed the focus value for the telescope's camera from the default value, you will most likely get an out of focus image. If it was cloudy when the telescope took its image, the clouds can act as diffusing or blurring filters. Even large temperature changes in the telescope can sometimes cause the telescope to take blurry images. The optics and metal parts expand or shrink on the telescope, causing the precise distance between the mirror and detector to change just enough to cause a blurry image. The image might be blurry because the tracking motor slipped a little.

### Contrast poor



You may want to PROCESS your image further.

How do you take an image that comes out?

Some things to consider:

When is your desired object visible in the sky? Make sure you choose the correct time and place to point the telescope, and don't forget that clouds block our view of the sky when it is cloudy.

How bright is your object in the sky? Make sure you choose to leave the shutter open long enough to allow enough light onto the detector, but don't leave it open so long that will saturate (fill up) the detector and cause an image flare (see above). The length of time the shutter is open is known as exposure time. Objects like single stars and planets are very bright, so they require shorter exposure times, while objects like nebulae and galaxies are faint, requiring longer exposure time.

There are other factors that affect whether or not your picture comes out. If you're looking for guidance, you can look at the MicroObservatory image archives and find a picture that you like and look at its Image Info. This will tell you what somebody else did to make a picture of that object come out. If you are taking a picture of the same object (or a similar object) you should be able to recreate a similar image, using the archived information.

## Notes on Implementation of Activities

Here is the list of computer-based activities and goals in the suggested implementation order. Where they exist, complementary hands-on activities are noted.

1. **MicroObservatory Guest Portal**
  - *Use the guest portal to take first images with telescopes*
2. **Introduction to MicroObservatory**
  - *Download and save images from guest portal usage*
  - *Use the telescope control page to take more images*
3. **Image Processing and Contrast**
  - *Use image processing software to learn about image contrast*
4. **Images as Data**
  - *Relate pixel values to light captured by detector*

- *Distinguish between observation and inference*
- 5. **Group Portrait of the Solar System: Taking Images**
  - *Create a set of images of the objects in the Solar System*
- 6. **Investigation of Jupiter and Its Moons: Taking Images**
  - *Take images of Jupiter and its moons over the course of one evening to study the motion of the moons*
- 7. **Group Portrait of the Universe: Taking Images**
  - *Create a set of images of the objects in the Universe*
- 8. **Investigation of Jupiter and Its Moons: Making a Movie/Making Sense of Images**
  - *Create a movie of Jupiter's moons*
- 9. **Advanced Image Processing**
  - *Learn more about image processing – false color, noise reduction, image calculator, etc.*
- 10. **Group Portrait of the Universe in Color: Taking Images**
  - *Take filtered (red, green, blue) images of objects in the Universe*
- 11. **Creating Color Images**
  - *Learn to create 3-color images using stock images, and then their own images*

## Vocabulary

**automated telescope:** An automated or robotic telescope provides a way for observers to collect data (images) without actually "observing." An automated telescope can be programmed to take a picture (or many pictures) of stars or other objects in the night sky. It can be useful for many types of projects. Examples might be photographing Jupiter every day, or capturing images of objects that are visible only at inconvenient hours, like the third quarter moon.

**bookmark:** A file within a browser in which an Internet user can save the addresses of interesting or frequently used Web sites, so that they are readily available for re-use.

**browser:** A program that allows a user to find, view, hear, and interact with material on the World Wide Web. Netscape Navigator and Microsoft Internet Explorer are examples of popular browsers.

**download:** To transfer (copy) files from one computer to another. "Download" can also mean viewing a Web site, or material on a Web server, with a Web browser.

**e-mail (electronic mail):** Messages sent through an electronic (computer) network to specific groups or individuals. Though e-mail is generally text, users can attach files that include graphics, sound, and video. E-mailing requires a modem to connect the telephone line to the computer, and an e-mail address. E-mail addresses include the @ symbol.

**favorite:** In Internet Explorer, a favorite is a collection of Web addresses selected by the user. Favorites are stored in a folder and are accessed by

selecting the Favorites menu. Favorites provide an easy way to organize the Web addresses of interesting sites.

**internet:** A "network of networks" linking millions of computers worldwide for communications purposes. The Internet was originally developed in 1969 for the U.S. military and gradually grew to include educational and research institutions. Today commercial industries, corporations, and residential users all communicate using the Internet. The World Wide Web is a collection of interactive documents accessible via the Internet.

**link:** A word, phrase, or image highlighted in a hypertext document to act as a navigation aid to related information. Links may be indicated with an underline, a color contrast, or a border.

**upload:** Copying or sending files or data from one computer to another. A Web developer, for example, could upload a document to a Web server.

**web interface:** A window screen that can be accessed through the Internet. Through this window you can interact or communicate with another device usually located away from you. In our case an observer can communicate with the MicroObservatory telescopes through a web form – the web interface - found on the MicroObservatory web site.

**world wide web:** A vast collection of files, including text, graphics, and other data linked through the Internet.



# MicroObservatory Guest Portal

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## Goals

- Understand that the Guest Portal allows users to remotely control the MicroObservatory telescopes
- Use the Guest Portal to take images
- Learn that different objects require different exposure times (optional)

## Activity Overview

This activity introduces participants to the MicroObservatory telescopes through the Guest Portal. Participants choose which object the telescopes will photograph. They receive an email with a link to the image after it is taken. They may explore the concept of exposure time as they choose what the correct exposure time for a given object is, although this may be left for the second time they take images with Guest Portal. See the Follow up section for more.

## Background

The Guest Portal has 5 categories, under which, there are many celestial objects participants can choose to image.

- Galileo** – contains some of the objects that Galileo observed
- Colorful Cosmos** – contains nebulae that are colorful
- Black Hole Search** – contains objects or areas of the sky known to harbor black holes.
- Galaxies Galore** – contains spiral, irregular and elliptical galaxies
- Telescope as Time Machine** – contains an assortment of objects at different distances from Earth

With the changing of the seasons on Earth, there is a change in what objects are visible in the night sky. Objects that are visible in the night sky in June may not be visible in December. These changes are a result of the

Earth's motion around the Sun – as the Earth moves along its orbit, the Sun's position with respect to the stars changes.

## Preparation

Space Required: Computer Lab

Materials:

- ❑ 1 Computer for every 1-2 participants

Preparation time: ⌚ ⌚

Activity time: 30 minutes

Gathering of materials and final preparations:

- ❑ Go to the MicroObservatory web site:  
<http://mo-www.harvard.edu/MicroObservatory>. Add this page to the Favorites (or bookmark this page) if not done so already to make it easy to return to the telescopes whenever you want.
- ❑ Become familiar with all the objects in the guest portal. As explained in the Background section, some of them will not be available due to the season. These will be greyed out.
- ❑ Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during the activity.

## Procedure

Discussion lead-in:

Introduce MicroObservatory telescopes to the participants and tell them they will be able to take images of stars, planets, galaxies and nebulae using telescopes located around the US (currently in Cambridge, MA and Arizona).

Take Images:

1. Have participants open the MicroObservatory home page (<http://mo-www.harvard.edu/MicroObservatory>) and click on “**Try it yourself. Visit our Guest Observer Portal!**”. A new window will pop up with links to the five different categories.
2. The **Galileo** or **Telescope as Time Machine** are good starting categories, as many of the youth will want to take images of objects they are familiar with, such as the Moon.

3. Have the participants read and follow the instructions on the screen.
  - ❑ **Getting Started** – read the paragraph and have participants notice where on the map the telescopes are located. **Click Continue**
  - ❑ **Select an Object** – have participants select an object and read the orange text that appears on the screen. **Click Continue**
  - ❑ **Exposure Time** – have participants choose an exposure time for their object. Each object will have a different exposure time, based on the brightness of that object. The portal will give feedback to the participant if they choose the wrong time and they will not be able to continue until the correct time is selected. **Click Continue**
  - ❑ **Your Info** – have participants enter their email address, and choose their age and State. **Click Continue**
  - ❑ **Review Request** – have participants review their request. If needed, they can edit their target or email address (exposure time will always be correct). **Click Submit**

## Follow up

Participants can use the images they took during the first session to generate questions about exposure time versus object type. They can then go back to the Guest Portal and make note of the exposure times needed for their object.

If you have requested access and have enrolled the participants, they will learn to use the Telescope Control page to take images.

## Watch Out For

- ❑ There is a tendency to refer to the MicroObservatory telescopes as a website, rather than a network of telescopes, controlled remotely via a website. It is important to stress the fact that the youth are controlling telescopes, very much in the same way professional astronomers do – using a computer to schedule observing time. Where possible, refer to MicroObservatory as remotely controlled telescopes, rather than a website.

## Vocabulary

**celestial object:** A natural object, like a star, planet, comet, galaxy, etc. that is observable in the sky.

**exposure time:** The period of time a telescope's light-sensing camera collects light coming from the source one wants to take an image of. The longer the exposure time, the more light that the telescope can gather to

make an image. The recommended exposure time varies for various targets: faint targets, such as far away galaxies, require long exposure times; bright targets, such as the Moon, require short exposure times.

**filter:** A device (a plastic film) that prevents some of the light from the celestial source to reach the light-sensing camera.

**target:** In astronomy the celestial object one takes a picture of is called target.

## **Useful Websites**

MicroObservatory Website:

<http://mo-www.harvard.edu/MicroObservatory>

# How to Take and Save Images with MicroObservatory

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Adapted with permission from *From the Ground Up!*

## Goals

- View, download, and save images taken with MicroObservatory
- Take images with full user access, using the **Telescope Control** page on the MicroObservatory (MO) website

## Activity Overview

In this activity participants practice the process of retrieving their images and properly save them to be able to use them in subsequent investigations. They also learn the basics of how to take an image using the **Telescope Control** page.

## Background

The FITS-format contains all the original information in the image— more than in the GIF-format version. They should always use the FITS format image if you plan to measure the brightness of the image. FITS images can be viewed using the MO Image processing program.

## Preparation

Space Required: Computer lab

Materials:

- A computer for each participant (or two)
- Internet access for all computers
- Personal area on computer to store images for each participant
- Observation log sheet

Preparation time: ⌚

Activity time: 45 minutes

Gathering of materials and final preparations:

- You need to create a storage area (a folder) where each participant will save his/her images for the rest of the program. Make sure you think about this in advance and avoid changing storage system half way during the program.
- Review the process for taking images using the **Telescope Control** page by referring to the section in the introduction.
- Become familiar with the typical problems that participants may encounter when taking images. These problems can be found both in the introduction and in the **Watch Out For** section at the end of this activity.
- Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during the activity.

## Procedure

Discussion lead-in:

You are about to control a powerful astronomical telescope from the convenience of your computer lab. This wonderful new technology has made possible a revolution in astronomy education. No longer does astronomy require shivering in the cold while standing in line for a ten-second glimpse through a telescope.

Emphasize to participants that good work habits with the telescopes will save headaches further along. For example:

- Download and save image files as soon as possible after the images are taken. Images remain on the Web for only a few days; once gone, they cannot be retrieved.*
- Name the image files clearly. The images may be needed again for future explorations or participant projects. (For example an image of the Ring Nebula taken with a red filter should be named `RingNebula_red.FITS`)*

Accessing the Image

1. Have participants check their email for a message from MicroObservatory. There should be a message with a link to the image they requested with the Guest Portal. They should click on the first link in the email. It will take them directly to the page with a thumbnail of the image along with information about the image.

2. They can click on the thumbnail to get to the image page where they can download the GIF or FITS file. They can also check what the weather was like when the image was taken, and all the information about how and when the image was taken.

#### On the image page – Saving Images

1. Participants will need to download the image in its original FITS-format. To do this, they need to click on the link above the image.
2. The name of the image file contains the first few characters of the name of the target, followed by a string of 12 digits that tells exactly when the image was taken (mo da yr hr min sec). The time the image was taken is given as *Greenwich Mean Time*, to follow a convention adopted by professional astronomers. *Greenwich Mean Time* is typically 6 hours ahead of *Eastern Standard Time*. As they save the image, they can keep this long filename or, if they prefer, rename the image.

**Make sure to clearly explain how and where participants should save their files on the computers in your lab.**

**Make sure to have a list of the participants usernames and passwords that you set up when enrolling them in MicroObservatory.**

#### Taking Images

1. Either have a generated list of objects (from the pull-down list) that the youth can choose from or have them brainstorm what type of object they would like to take an image of before beginning. This will help focus them once they get started. For this first time, it is best that they choose an object that is in the pull-down menu.
2. Have participants click on **telescopes** on the left navigation panel of the MicroObservatory home page.
3. The next set of steps can be done in whatever order makes the most sense to them.
  - Check the weather at the telescope sites by clicking on the city name.
  - Check the availability of times at the telescopes by clicking on the queue. Remember that images can be taken 3 minutes apart.
  - Check when an object will be up by click on **what's up** on the left navigation of the Select Telescope page.
4. Once they have selected a telescope, object, and know when they should take the image they are ready to go to the Control Telescope

page by clicking on the **red dot** on the map for the telescope they want to use. The telescope name will appear at the top of the Control Telescope page. Make sure participants check to make sure they chose the correct telescope.

5. The following steps are explained in detail in the introduction to MicroObservatory.
  - Enter username and password
  - Choose “At Night” (only the Moon can be images during the day)
  - Enter the time – be sure the correct AM/PM is chosen
  - Choose the object from the list
  - Enter exposure time under Main Camera, max time is 60 seconds

<b>Object</b>	<b>Time of day</b>	<b>Select target with...</b>	<b>Exposure Time</b>	<b>Filter</b>
<b>Moon</b>	Day or Night	Pull-down Menu	0.1 - .05 sec	Grey (Neutral Density Filter)
<b>Planets</b>	Night	Pull-down Menu	0.1 – 2.0 sec	Clear (No Filter)
<b>Stars</b>	Night	Coordinates	0.1 – 10 sec	Clear (No Filter)
<b>Star clusters</b>	Night	Pull-down Menu or Coordinates	5 – 30 sec	Clear (No Filter)
<b>Nebulae</b>	Night	Pull-down Menu or Coordinates	45 – 60 sec	Clear (No Filter)
<b>Galaxies</b>	Night	Pull-down Menu or Coordinates	45 – 60 sec	Clear (No Filter)
<b>Asteroids / Comets</b>	Night	Coordinates	15 – 60 sec	Clear (No Filter)

- They can choose a filter, if needed (Grey for the moon)
- Leave Zoom and Focus with default settings
- Click Take Picture

## Watch out for...

Here are some things to consider when taking images with the MicroObservatory telescopes.

- ❑ When is your desired object visible in the sky? Make sure you choose the correct time and place to point the telescope, and don't forget that clouds block our view of the sky when it is cloudy.
- ❑ How bright is your object in the sky? Make sure you choose to leave the shutter open long enough to allow enough light onto the detector, but don't leave it open so long that will saturate (fill up) the detector and cause an image flare (see above). The length of time the shutter is open is known as exposure time. Objects like single stars and planets are very bright, so they require shorter exposure times, while objects like nebulae and galaxies are faint, requiring longer exposure time.
- ❑ There are other factors that affect whether or not your picture comes out. If you're looking for guidance, you can look at the MicroObservatory image archives and find a picture that you like and look at its Image Info. This will tell you what somebody else did to get a good image of that object. If you are taking an image of the same object (or a similar object) you should be able to recreate a similar image, using the archived information.

## Vocabulary

**FITS-format:** FITS stands for Flexible Image Transport System, and is an image file format widely used by the astronomical community. It's great advantage over more familiar image file formats, is that it can, and often does, contain information about the imaging device used to capture the image, and more importantly, the time, date, and location of the telescope used. Additionally, each pixel of a FITS file will often be linked to the Right Ascension and Declination of the portion of the sky imaged. Moving a cursor across such a calibrated image enables an astronomer to determine the positions and names of the stars in the field of view.

## Useful Websites

Technical description of the MicroObservatory Telescopes:  
<http://mo-www.harvard.edu/MicroObservatory/> then click "About Us"

Quicktime Movies of the MicroObservatory Telescopes:  
<http://mo-www.harvard.edu/MicroObservatory/> and then click on the link on the main page.



# Image Processing and Image Contrast

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## Goals

- Learn how to use MicroObservatory Image 2.0 to process images
- Apply newly gained knowledge of pixel value to solve a contrast challenge

## Activity Overview

This activity is for youth to explore some key tools of MicroObservatory Image, the image processing software, namely “Adjust Image” – which allows them to change the contrast of the image, the “magnifying glass” – that enables zooming in on a specific part of the image, and “Measure” – which allows the youth to find the high and lowest pixel value in a selected area of the image.

## Background

Each pixel is associated with a pixel value that is proportional to the number of light particles captured by the corresponding pixel on the MicroObservatory detector. The higher the pixel value the more particles of light were captured by the detector.

A CCD camera attached to a telescope “sees” differently from the human eye. A main difference is that the CCD is usually color-blind, i.e. it only records white, black and shades of gray depending of the intensity of the light that falls on the CCD.

A CCD (charge-coupled device) is an electronic instrument for detecting light. In the case of an astronomical CCD camera, this light is usually very dim. The heart of the CCD consists of a thin silicon wafer chip. The chip is divided into thousands or millions of tiny light sensitive squares called pixels.

Each pixel on the detector corresponds to an individual pixel in the final image. When a photon of light strikes the surface of certain materials (like

the silicon in a CCD chip) the energy imparted by the photon can release an electron from the material. In a CCD, this electron is stored within the walls of a pixel. During a long exposure, photons rain down from the celestial object being imaged and strike the CCD detector. The pixels in the detector act like wells and begin to fill up with electrons (generated by the photons impacting the chip). If an area of the CCD is imaging a bright object such as a star (which gives off lots of photons), the pixels in that area fill up with more electrons than those in an area imaging something dim like faint nebulosity or the black night sky. (Though even the pixels imaging black sky will end up containing some electrons for several reasons.) Once the exposure is finished (usually done by closing a shutter on the camera), the charge must be transferred out of the CCD and displayed on a computer monitor.

A numerical value is assigned to each pixel's charge, based on the number of electrons contained in the pixel. This value is sent to a computer and the process repeats until each pixel's electrons have been converted to a pixel value and are displayed as a raw image on the computer screen.

No matter how we change the way we display this raw image using our image processing software, the information contained in the image, namely the number of photons that originally were captured by each individual pixel in the CCD detector, remains the same.

## **Preparation**

Space Required: Computer lab.

Materials:

- Computer every 1-2 participants
- MicroObservatory Image software installed on each computer

Preparation time: ⌚ ⌚

Activity time: 30 minutes

Gathering of materials and final preparations:

Be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during the activity.

# Procedure

## Discussion lead-in:

You can explain that the CDD camera attached to the MicroObservatory telescope “sees” differently from the human eye. A main difference is that the CCD is usually color-blind, i.e. it only records white, black and shades of gray depending of the intensity of the light that falls on the CCD. But that is not all. Using MicroObservatory Image we can change the contrast of the image and how the image looks to us.

## Image Processing:

1. Have participants save an image of the Butterfly Cluster or of the Pleiades in FITS image format. Beautiful images of these clusters can be found in MicroObservatory Archive (get images → Image Archive Directory → Star Clusters). They should follow the directions for downloading and saving on the web page containing their images.
2. With the MicroObservatory image processing tool, have participants open the image of the star cluster or other image where stars are resolved. They should go to **File** and select **Open image on local disk**. Then choose the specific file for that image. The image will open in a new window.
3. **Adjust the image display.** Have the youth go to the **Process** menu and select **Adjust Image**. When the dialog box appears, and BEFORE they hit AUTO (**linear scale**), have them read the max and min values on the contrast scale. They may then click on the **Auto** button: the program will automatically adjust the contrast of the image.
4. **Zoom in.** Have participants click on a star in your image then, using the **magnifying glass** tool (on the upper left of the image), zoom in on the star until the individual pixels that make up the star can be distinguished.
5. **Pixel value.** Have participants click on the image and move the cursor on different parts of the image. The **Image Info** window shows the X, Y coordinates for each pixel that forms the image. **Pixel Value** indicates how many counts are associated with that pixel. The number of counts is related to the number of particles of light that have been collected by each pixel. In simple terms though we can say that, “Pixel value tells us how many light particles were captured by that specific pixel.”
6. **Find the highest and lowest pixel value in a region of the image.** Have participants use the **circle** feature (in the upper left of the image window) to make a circle on your image. They should center the circle on a star (after a circle has been made, it can be dragged to different

positions within the image). Tell the youth to go to the **Process menu** and select **Measure** from the menu. A table will appear in the upper left of the image that shows some information about the region of the image within the circle you made. *Name* is the name of the region, *Area* is the total number of pixels in the area surrounded by the circle, *Mean* is the average pixel value in that region, *Total* is the sum of all pixel values for that region, *Min* the lowest pixel value in that region, *Max* is the highest pixel value in that region. (note that  $Mean = Total/Area$ )

7. **Have participants use the Measure tool** to find the max and the min number of counts collected by a pixel in the area you selected. Have the youth make a circle of the same radius (size of the circle is shown at the top of the window you are working in) in different regions in the same image and compare the mean number of counts for all regions.
8. **Changing Contrast.** In the **Adjust Image** window change the value of the min value: *What happens to the image?* Then change the max value: *What happens to the image?* By changing the max and min values we change the grey scale used to display the image, we change the contrast of the image. NOTE that **we only change how we display the information contained in the image, we do not change the information** (i.e. how much light has been collected by each pixel).
9. **Discuss with a partner.** Have participants explain to each other what the meaning of min and max value is on the contrast scale. Ask them the following questions:  
  
*If you change the min value what happens to the image? Why? Write down your explanation.*  
*If you change the max value what happens to the image? Why? Write down your explanation.*
10. After the participants write down their hypotheses, they should have the opportunity to test them by engaging in the image processing challenges.

### Contrast Challenges

Youth are divided in two groups: GROUP A and GROUP B and in each group youth work in pairs.

All computers should have the MicroObservatory web site open at "Latest MicroObservatory Images" page (click on "Get Image") and the MO image processing software window open side by side.

### **GROUP A: Whirlpool**

Have participants open a good image of the Whirlpool Galaxy (use “click and drag” on Macs). Tell them to process the image using the linear scale, hit AUTO, and then adjust the contrast to get a crisp image.

**Challenge** the youth to change the max and/or min value **ONLY ONCE** to make the arm, which connects the two galaxies, disappear (any other processing tool can be used, but min and max can be changed only once).

*How did you make the arm disappear? Explain your reasoning*

### **GROUP B: Orion Nebula**

Have participants open a good image of the Orion Nebula (use “click and drag” on Macs). Tell them to process the image using the linear scale, hit AUTO, and then adjust the contrast to get a crisp image.

**Challenge** the youth to change the max and/or min value **ONLY ONCE** to bring out the stars in the center of Orion (any other processing tool can be used, but min and max can be changed only once). If this is too difficult, youth can first try to isolate the star in the top part of the Nebula.

Then ask: *How did you bring out the stars (and make the nebula disappear)? Explain your reasoning*

### Discussion

Each group then reflects on the meaning of the max and min values on the contrast scale. After working on these challenges have them answer again the following questions:

*If you change the min value what happens to the image? Why?*

*If you change the max value what happens to the image? Why?*

Compare your most recent answers with the hypotheses they made earlier: do they agree? If yes, why? If not, why?

### Wrap Up

All groups share their finding and the facilitator points out first those statements that seem problematic. The facilitator may offer some clues about why they seem problematic and allow the youth in that group and other groups to formulate an alternative explanation. Finally the facilitator highlights the correct statements that the youth were able to formulate on their own and completes/improves them if necessary.

## **Follow up**

Ask the youth who worked on the Whirlpool challenge to facilitate the activity for the youth who worked on the Orion challenge and vice-versa. To have to teach others will have the youth understand the importance of giving clear directions and explanations. It will also help them understand their activity better.

## Watch out for...

- ❑ It is important that for this activity the youth have a practical understanding of the particle model of light. In this model a beam of light can be compared to a stream of tiny particles all moving at the same speed (the speed of light). Each particle is characterized by its energy, or color. A beam of white light is a stream of particles of all the colors found in a rainbow. When light hits a CCD detector each individual light particle is captured by one of the pixels of the detector and is counted. Pixels that have large counts have collected more light particles than pixels with small counts.
- ❑ Watch closely your own vocabulary to make sure to convey the message that by changing values on the contrast scale we are **changing the display** of the image not the image.
- ❑ An image is a collection of pixels, and each pixel is associated with a number, the pixel value.

## Vocabulary

**CCD:** CCD stands for charge-coupled device. A CCD is a detector made on a silicon wafer. Due to the physical nature of silicon, photons of light that hit it generate electrons in the silicon. The job of the CCD is to collect these electrons in its "light buckets" (called **pixels**) during the length of the exposure to light. The more light falling on a particular "light bucket" or pixel, the more electrons that pixel will contain. The buckets then transfer their electrons (think of a "water bucket brigade") out to the CCD controller (which contains the electronics to control the CCD) and on to the computer. The computer then regenerates the image.

**contrast:** Contrast is the difference between the darkest and lightest areas in an image. The greater the difference, the higher the contrast.

## Useful Websites

Starizona: <http://www.starizona.com/> This website is designed to teach you how to take CCD images and to process them to achieve impressive results. It is also intended to be a showcase of CCD imaging to inspire you to head out under the stars and capture beautiful pictures!.

Astronomy Picture of the Day: <http://antwrp.gsfc.nasa.gov/apod/> Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer:



# Images as Data

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## Goals

- ❑ Relate the exposure time of an image to the amount of light captured in the image
- ❑ Learn that the pixel value associated to each pixel in the image provides information about how much light originally emitted by the object (source) has been collected by that pixel

## Activity Overview

In two groups, participants will open a series of images in the MicroObservatory Image software and make observations. They will learn how to read a “FITS header,” how to measure the amount of light a given pixel has detected, and make comparisons between before discussing their findings.

## Background

A CCD camera attached to a telescope “sees” differently from the human eye. A main difference is that the CCD is usually color-blind, i.e. it only records white, black and shades of gray depending of the intensity of the light that falls on the CCD.

A CCD (charge-coupled device) is an electronic instrument for detecting light. In the case of an astronomical CCD camera, this light is usually very dim. The heart of the CCD consists of a thin silicon wafer chip. The chip is divided into thousands or millions of tiny light sensitive squares called pixels.

Each pixel on the detector corresponds to an individual pixel in the final image. When a photon of light strikes the surface of certain materials (like the silicon in a CCD chip) the energy imparted by the photon can release an electron from the material. In a CCD, this electron is stored within the walls of a pixel. During a long exposure, photons rain down from the celestial object being imaged and strike the CCD detector. The pixels in the detector act like wells and begin to fill up with electrons (generated by the photons impacting the chip). If an area of the CCD is imaging a bright object such as a star (which gives off lots of photons), the pixels in that area fill up with more electrons than those in an area imaging something dim like faint nebulosity or the black night sky. (Though even the pixels

imaging black sky will end up containing some electrons for several reasons.) Once the exposure is finished (usually done by closing a shutter on the camera), the charge must be transferred out of the CCD and displayed on a computer monitor.

A numerical value is assigned to each pixel's charge, based on the number of electrons contained in the pixel. This value is sent to a computer and the process repeats until each pixel's electrons have been converted to a pixel value and are displayed as a raw image on the computer screen.

No matter how we change the way we display this raw image using our image processing software, the information contained in the image, namely the number of photons that originally were captured by each individual pixel in the CCD detector, remains the same.

## **Preparation**

Space Required: Computer Lab

Materials:

- Computer every 1-2 participants
- MicroObservatory Image software installed on each computer
- Observation log sheets for all participants

Preparation time: ⌚ ⌚

Activity time: 60 minutes

Gathering of materials and final preparations:

In the week before you facilitate this activity practice the activity as if you were a participant and try to anticipate any factor that would distract the participants from their main task: making observations. Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during the activity.

## **Procedure**

Discussion lead-in:

To be able to make good observations is a key skill in all sciences, and in everyday life as well. Because observations constitute the evidence on which scientific models are based, it is important to practice good observations skills and to be able to distinguish between an observation and an inference.

In astronomy observations are mostly limited to what can be seen when looking at an object and what can be measured; i.e. the light from that object that has been collected by a telescope's detector. For example, observations can be based on the appearance of the image of the object and on the information about the amount of light displayed by each pixel in the image. That information is data.

Explain to the participants that they will first observe and describe to each other what they see in some MicroObservatory images. They will make observations about the image: shape, size, different shades of grey. Have youth focus on the details, and remind them about the difference between observations and inferences. In addition, mention that observations are not only about what we see in an image, but are also based on the information associated with each pixel in the image. Make sure participants use all the MicroObservatory Image software tools that enable them to find out how much light was captured by each pixel.

Form two groups:

Group A will work with images of the Andromeda Galaxy (taken using different exposure times), Group B will work with images of the Orion Nebula (taken using different filters).

Youth in both GROUP A and GROUP B work in pairs.

All computers should have the MicroObservatory web site open at "Latest MicroObservatory Images" page (click on "Get Image") and the MO image processing software window open side by side.

### **GROUP A**

With MO Image processing tool open the following images (use "click and drag" on Macs) in the MicroObservatory Archive:

#### **Get images → Image Archive Directory → YAA General**

abdi	M-31Andromed103106014513.GIF	31-Oct-06 01:45	MA	Ed
abdi	M-31Andromed103106013920.GIF	31-Oct-06 01:39	MA	Ed
abdi	M-31Andromed103106013528.GIF	31-Oct-06 01:35	MA	Ed

Hve the youth set the contrast settings for these images are: Max = 850 and Min = 650 (to start, then you may use other Max and Min values but try to use the same values for all images).

If some pairs are faster than other going through the process you can ask them to make predictions on what would happen if the exposure time for taking the image was set to 10 sec. After they make their predictions youth can check if they were correct by using this image (exp. time = 5 sec)

abdi	M-31Andromed103106012355.GIF	31-Oct-06 01:23	MA	Ed
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## GROUP B

With MO Image processing tool open these images of Orion Nebula images (use “click and drag” on Macs) in the MicroObservatory Archive and set the contrast settings for each image as indicated.

**Get images → Image Archive Directory → YAA General**  
iporro M-42OrionNeb112407060026.GIF 24-Nov-07 06:00 MA Donald  
*Contrast settings: Max = 1100 Min = 550*  
iporro M-42OrionNeb112407055421.GIF 24-Nov-07 05:54 MA Donald  
*Contrast settings: Max = 600 Min = 275*  
iporro M-42OrionNeb112407055131.GIF 24-Nov-07 05:51 MA Donald  
*Contrast settings: Max = 600 Min = 275*  
iporro M-42OrionNeb112407054842.GIF 24-Nov-07 05:48 MA Donald  
*Contrast settings: Max = 600 Min = 275*

For both Group A and Group B

1. Under “Window” choose “Fits Header”

This file provides important information about when and how this image was taken and who took it. Some of the information in this file may not be very familiar to the participants immediately. For the time being they should focus on the following important pieces of information:

FILE = name of the file  
DATE = when the image was taken  
EXPTIME = exposure time  
START-OBS and OBS-END = Starting and ending time of the exposure  
FILTER = filter used when taking this image  
TELESCOP = name of the telescope used to take this image  
OBSERVER = who took the image  
OBJECT = name of the object in the image

**Observations can be based on the appearance of the image and on the information provided by each pixel. That information is data.**

Have the youth observe and describe to each other what they see, focusing on details, making observations about the image: shape, size, different shades of grey. Remind them to make distinctions between observations and inferences. We are interested in observations only (for example: an image does not show stars. The image shows white dots, some bigger some smaller. Some dots are white, other are grey, different shades of grey, and so on).

*Record some of your key observations on chart paper. Can you identify any pattern in what you observed? Describe the pattern(s) in your own words.*

2. Have the participants focus on the information provided by each pixel. Instruct them to click on one image and move the cursor on different parts of the image. The “*Image Info*” window the X, Y coordinates for each pixel that forms the image. “*pixel*” tells how many counts are associated with that pixel. The number of counts is related to the number of particles of light that have been collected by each pixel. In simple terms, we can say that “*pixel*” tells us how many light particles were captured by that specific pixel.
3. Introduce participants to the circle and the “Measure” tool, under the process menu, to compare the same region in all the images. Have the youth take a circle of the same radius (size of the circle is shown at the top of the window you are working in) for all images and center it on the same region. They should compare the pixel values for the same region in all images and compare the mean number of counts for all images.

*What image has the highest mean number? What image has the lowest mean number? Why do you think is that?*

Ask them to make a hypothesis and explain their reasoning. They should record ytheir observations and any suggested explanations on chart paper.

4. After making several observations about these images, participants should describe what is the same and what is different in the images. Can they identify any pattern in what you observed? Have them describe the pattern(s) in their own words.

*What do you think is the reason for the differences in the images? Make your hypothesis and explain your reasoning. Can you test your hypothesis?*

#### Group Discussion

**Question for GROUP A: how does the exposure time of the observation affect the image that MicroObservatory takes?**

Example of answer based on observations: *images taken with longer exposure times show dots that look bigger and bigger as the time increases. Or: If each pixel collects light then longer exposure times result in more light collected by each pixel and in the whole image. Or: Longer exposure times allow more light to be captured by the telescope and images show more details. Etc...*

**Question for GROUP B: how does the use of different filters affect the image that MicroObservatory takes?**

Example of answer: *We see different “things” when we use different filters for example the dots in the images taken with a filter look smaller, and some dots do not show up at all. Or: When we use a filter there is always less amount of light in the image than when we use NO filter. Or: Filters cut the amount of light that reaches the detector. Or the blue filter seems to block most of the light and the red filter seems to block the least amount of light .... The neutral density filter also blocks a lot of light.*

**GROUP A and GROUP B share their findings**

- Form new pairs with one person from Group A and one from Group B. Person A and person B describe to each other what they observed in the images and the conclusions they got to.
  
- Have larger groups with representatives from both GROUP A and GROUP B discuss the following prompts:

*How do exposure time and filters affect an image taken with MicroObservatory?*

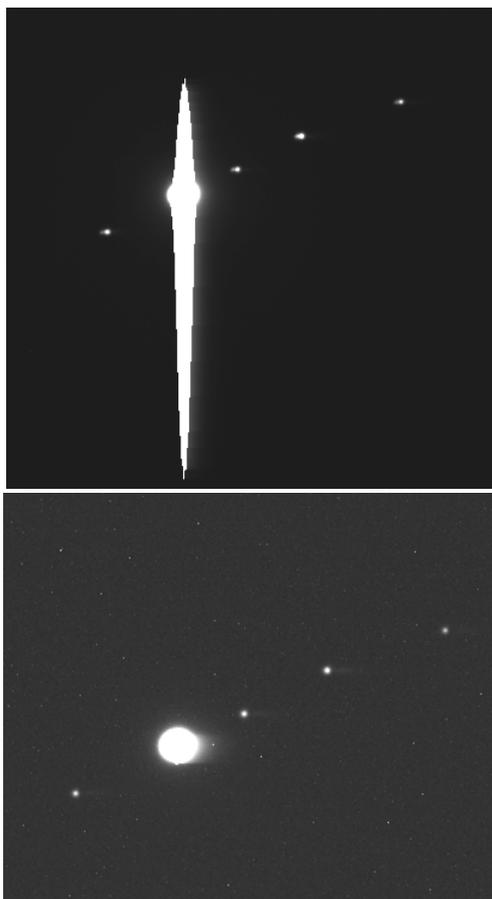
*What is similar what is different?*

*How would you use them in combination?*

## **Follow up**

This is an integral part of the activity and enough time should be allocated to the activity to have time to introduce the Jupiter challenge (Note, in case Jupiter is not visible in the sky when you do this activity, Saturn and its moons can be used instead. In neither Saturn or Jupiter are visible, ask youth to make their predictions and then ask them to find evidence to support their predictions using the images stored in the Image Archive Directory.

Present the following challenge: An image of Jupiter taken with 1 sec exposure time and no filter allows you to see the moons of Jupiter but Jupiter itself looks overexposed. Ask how we can you get an image of Jupiter were you can see the moons but Jupiter itself is not overexposed? (Note both images were taken with Zoom in).



Jupiter and its Moons  
Exposure time = 1 sec, no filter

### Jupiter and its Moons

Ask participants to provide three different settings for the telescope that they predict will result in an image like this one. Have them write down their settings and take images of Jupiter using all the proposed combinations.

### **Watch out for...**

- ❑ This activity is about making observations and reflecting on them. To make sure that youth can get the most out of this activity youth should already be familiar with the basics of searching for images on the MicroObservatory Image Archive Directory, and saving FITS files and opening them in MOImage.

- ❑ Make sure that youth are familiar with the basic software tools that they will have to use: Adjust Image, Zoom in (magnifying glass), and Measure. The Measure tool is very useful but it may be more difficult to understand for some youth. DO NOT require that they all use this tool. Youth must however be able to read the information in the Image Info window, and to browse the image to find the pixel value for specific pixels.
- ❑ The Jupiter challenge is a key component of the all activity: make sure that each pair of participants takes images using at least three different set of settings. Allow time during the next session for the youth to check their images, verify what set of settings works best and reflect on why that was the case. Before next session you need to make sure to review the participants images and select the one that produce the right results. Have a set of best images ready with the telescope settings that they use. Emphasize the fact that there is not just one way to get the image right: different combinations of exposure time and choice of filter can provide the same result. Why is that?

## Vocabulary

**CCD:** CCD stands for charge-coupled device. A CCD is a detector made on a silicon wafer. Due to the physical nature of silicon, photons of light that hit it generate electrons in the silicon. The job of the CCD is to collect these electrons in its "light buckets" (called **pixels**) during the length of the exposure to light. The more light falling on a particular "light bucket" or pixel, the more electrons that pixel will contain. The buckets then transfer their electrons (think "water bucket brigade") out to the CCD controller (which contains the electronics to control the CCD) and on to the computer. The computer then regenerates the image.

**contrast:** Contrast is the difference between the darkest and lightest areas in an image. The greater the difference, the higher the contrast.

**data:** A collection of facts or information from which conclusions may be drawn. In computer science, data is used to describe information that is stored and/or processed digitally.

**inference:** A deduction or conclusion made from facts that are suggested or implied rather than overly stated. Drawing meaning from a combination of clues in a given context without explicit reference to that context. "The sky was dark and cloudy so I took my umbrella." We can infer that it might rain even though there is no reference to an actual observation of a rain storm.

**observation:** The process of using one's senses to perceive and record information about some aspect of the natural world. Also, the act of making and recording a measurement.

# Additional sets of images that can be used for this activity

## IMAGES for GROUP B

### Orion Nebula

#### Get Images → Image Archive Directory → YAA General

iporro M-42OrionNeb112407060026.GIF 24-Nov-07 06:00 MA Donald

*Contrast settings: Max = 1100 Min = 550*

iporro M-42OrionNeb112407055421.GIF 24-Nov-07 05:54 MA Donald

*Contrast settings: Max = 600 Min = 275*

iporro M-42OrionNeb112407055131.GIF 24-Nov-07 05:51 MA Donald

*Contrast settings: Max = 600 Min = 275*

iporro M-42OrionNeb112407054842.GIF 24-Nov-07 05:48 MA Donald

*Contrast settings: Max = 600 Min = 275*

### Lagoon Nebula

#### Get Images → Image Archive Directory → Light and Color

acontos M-8LagoonNeb050201135546.GIF 02-May-01 13:55 HI Ben

*Contrast settings: Max = 800 Min = 400*

acontos M-8LagoonNeb050201142831.GIF 02-May-01 14:28 HI Ben

*Contrast settings: Max = 540 Min = 360*

acontos M-8LagoonNeb050201143223.GIF 02-May-01 14:32 HI Ben

*Contrast settings: Max = 440 Min = 360*

acontos M-8LagoonNeb050201143606.GIF 02-May-01 14:36 HI Ben

*Contrast settings: Max = 390 Min = 450*

With this set of images the compare and contrast activity can be also made using the log scale and then Auto. The pixel values and don't change of course, only the way the data is displayed.

Using the log scale has the great advantage to clearly show that each image is different from the other (region that is visible, size, shape, intensity of light coming form different regions). The disadvantage is that the Min and Max value on the contrast scale have a difference meaning than when using the linear scale: in particular increasing the Max value does not meaningfully affect how the image is displayed.

### M-3 Globular Cluster

#### Get Images → Image Archive Directory → Light and Color

abwo2 M-3Globularc032801075753.GIF 28-Mar-01 07:57 AZ Donald

*Contrast settings: Max = 404 Min = 193*

abwo2 M-3Globularc032801080107.GIF 28-Mar-01 08:01 AZ Donald

*Contrast settings: Max = 210 Min = 193*

abwo2 M-3Globularc032801080628.GIF 28-Mar-01 08:06 AZ Donald

*Contrast settings: Max = 249 Min = 193*

abwo2 M-3Globularc032801080932.GIF 28-Mar-01 08:09 AZ Donald

*Contrast settings: Max = 305 Min = 193*

### Crab Nebula

#### Get Images → Image Archive Directory → Nebulae

esalazar M-1CrabNebul031404063044.GIF 14-Mar-04 06:30 AZ Cecilia  
*Contrast settings: Max = 450 Min = 350*  
esalazar M-1CrabNebul031404063329.GIF 14-Mar-04 06:33 AZ Cecilia  
*Contrast settings: Max = 325 Min = 320*  
esalazar M-1CrabNebul031404063644.GIF 14-Mar-04 06:36 AZ Cecilia  
*Contrast settings: Max = 340 Min = 325*  
esalazar M-1CrabNebul031404063931.GIF 14-Mar-04 06:39 AZ Cecilia  
*Contrast settings: Max = 355 Min = 325*

## **Dumbbell**

### **Get Images → Image Archive Directory → Nebulae**

catherine M-27Dumbbell121303020354.GIF 13-Dec-03 02:03 AZ Cecilia  
catherine M-27Dumbbell121303020635.GIF 13-Dec-03 02:06 AZ Cecilia  
catherine M-27Dumbbell121303020921.GIF 13-Dec-03 02:09 AZ Cecilia  
*Contrast settings: Max = 350, Min = 315*

NOTE: Image taken with “clear” filter is not available in this set  
Same exposure time, different filters

# Investigation of Jupiter and its Moons: Part One

---

Adapted with permission from *From the Ground Up!*

## Goals

- Build a model illustrating Jupiter and its moons
- Reflect on their existing ideas about the possible motion of moons and make a concrete prediction based on these ideas.

## Activity Overview

Over the course of two activities, participants will recreate Galileo's process of discovering the moons of Jupiter. The youth will be presented with set of images from MicroObservatory of Jupiter and its moons taken at different times. They will first hypothesize on what these objects are; then build a three-dimensional model of the system demonstrating their predictions. The model will be representative of their thoughts on how these moons move. Finally, the youth take their own images.

## Background:

When Galileo Galilei peered through his telescope in 1610, he observed a row of four dots surrounding Jupiter in the sky. Initially believing them to be background stars, he made a sketch of his observation and continued to explore the sky. On subsequent observations, he was astounded to find that these "stars" appeared to move back and forth around the planet. Galileo had discovered the four largest moons of Jupiter.

Galileo successfully predicted that these objects orbited Jupiter in circles around the planet, rather than simply moving back and forth, following a straight line. He did this by imagining how motion that would seem to follow a circle when seen from above would appear when viewed edge-on.

His discovery was important, because it showed that *not* everything in the heavens revolved around the Earth: The idea that these four specks of light clearly revolved around the planet Jupiter was a useful contribution to a body of evidence that Earth was not the center of the Universe.

He could not have imagined what amazing worlds these moons would turn out to be. Today, nearly four centuries later, we have close-up views of these four moons, sent to us from spacecraft that have made the long journey to Jupiter, revealing four very different worlds.

## Preparation

Space Required: Computer Lab

Materials:

- A computer for every 1-2 participants
- A copy of the Observation Log Sheet for each participant
- Copies of the daily list of what planet is up in the sky at each of the telescope locations (optional)
- Images of Jupiter and its moons
- Foam balls of various sizes and modeling materials

Preparation time: ⌚ ⌚

Activity time: 45 minutes

Gathering of materials and final preparations:

Download images of Jupiter from the MicroObservatory Image Archive. There are several sets taken over short periods of time in the “Jupiter” section. Alternatively, you may take some yourself over the course of a few days. Make note of the proper sequence of your images and print copies for each group.

Print the images. Label with the date and time they were taken. Check to see that Jupiter is above the horizon at night so that it can be imaged from the MicroObservatory telescopes. Make copies of the Observation Log Sheets. Be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms will come up during the activity.

## Procedure

Discussion lead-in:

Tell the story of Galileo’s first observations of strange “dots” near Jupiter as outlined above. The facilitator should refrain from using the word

“moon” through the first part of this activity. Galileo continued observing these objects and, in doing so, made a discovery that contributed to our modern understanding of the Solar System. Now the participants will conduct a similar investigation.

### Examining the images of Jupiter

1. Divide the participants into groups of two to four and distribute a set of the images to each group. The images should be presented with the date and time they were taken.
2. Ask the youth to make observations of the images and make note of any interesting features. Some questions to ask:  
*Does anything change between these images?*  
*Does anything stay the same?*  
*Are there any objects that appear in only some of the images?*
3. Inform the participants that these images were taken of Jupiter over the course of several hours or several nights, depending on the set you choose. Make sure to bring attention to the “dots.” Ask them to begin thinking about what these “dots” surrounding the planet might be, if they haven’t already.
4. Have the participants record what they think the “dots” might be and why they think any changes in their position relative to Jupiter might have occurred.
5. Present the balls and modeling materials to the youth. Ask them to create a 3D model that accurately represents the system they are observing in the images. The models should be dynamic and changing in that they may be rearranged to represent any of the images the youth have seen.
6. Have participants share their models with another group and explain them.

### Making Predictions and Taking Images

1. Ask the participants to discuss any changes they believe might occur in future images and to sketch them out.
2. Invite the participants to take their own sequence of images of Jupiter with the explanation that their model should be able to illustrate the same images they create.

Depending upon the frequency of your sessions, you may choose to either coordinate a series of observations of Jupiter over the course of one night, have the youth take images at least once every day from home, or both. Images taken over a short period of time will emphasize the motion of the

inner moons, while an observing campaign that lasts several days will better show the motion of the outer moons.

## Follow up

In the following activity, participants will make an animated picture from the images they take as part of their sequence and test that their model is accurate.

## Watch out for...

- ❑ This activity asks that participants draw inferences from two-dimensional images and make predictions on the three-dimensional system they represent. This is a difficult jump conceptually. To prepare, it may be helpful for you to consider how a photograph of an every day object is actually a two-dimensional representation of its real world counterpart.
- ❑ Your participants may create a model of the Jupiter system that has its moons, or “dots,” march back and forth along a straight line, rather than following a circular orbit. Encourage the model builders in this situation to rethink their model. Ask them if the moons and Jupiter are on the same line, do they collide into each other?
- ❑ Jupiter is not visible at night at all times of year. If conducting this activity at a time when Jupiter is not visible, omit the imaging portion of the activity.
- ❑ As the participants are expected to make systematic observations of Jupiter with the MicroObservatory telescopes, it is important that they be especially careful to keep a good record of their work on their logsheets. They will be helpful in sorting out the images later. The regularity and quantity of the images they take will improve the quality of the animation they make later.
- ❑ Most image sets of Jupiter show the planet with a long “spike” running up and down through it. This happens as a result of imaging a very bright object. Participants may get hung up on making observations of the spike, rather than the “dots.”

## Vocabulary

**Callisto:** The second largest of Jupiter's satellites. Callisto is not geologically active and has a thin atmosphere. This combination means it has a very “old” surface, remaining almost entirely unchanged except for

accumulating craters, much like our own Moon. Its diameter is about 2980 miles (4800 km) and takes about 16.7 days to orbit Jupiter.

**Europa:** The fourth largest of Jupiter's satellites. Europa is a large, dense, icy moon of Jupiter. Its surface is covered with long, crisscrossing track ways (but few craters) and frozen sulphuric acid. Its diameter is less than 2,000 miles (3,138 km), smaller than the Earth's moon. It takes Europa 3.55 days to orbit Jupiter. Its mean distance from Jupiter is about 420,000 miles (670,900 km). It was discovered by Galileo and Simon Marius (independently) in 1610.

**Ganymede:** The largest of Jupiter's satellites, with a diameter slightly larger than Mercury's. It is the only moon known to have a liquid core generating its own tiny "magnetosphere." A compass would probably work on Ganymede. It is 3,270 miles in diameter (5262 km) and takes 7.15 days to orbit Jupiter.

**Gravity:** The most feeble of the four fundamental forces in the universe that affect all matter. Gravity is an attractive force. The magnitude of gravitational attraction depends directly on mass and inversely on distance squared. For instance, the gravitational attraction between you and the Earth is much greater than that between you and the Sun, even though the Sun is far more massive than the Earth (333,000 times). The distance separating you from the Sun weakens the mutual gravitational attraction so that the Earth's gravitational pull on you at Earth's surface is 1653 times greater than the Sun's.

**Kepler's relation:** Also known as Kepler's third law. Kepler's third law of planetary motion says that the average distance of a planet from the Sun cubed is directly proportional to the orbital period squared. Newton found that his gravity force law could explain Kepler's laws. Since Newton's law of gravity applies to any object with mass, Kepler's laws can be used for any object orbiting another object.

**Io:** The third largest of Jupiter's satellites and the closest to the planet. Io is the only body in the Solar System, other than Earth, to currently have active volcanos. Photographs taken by visiting unmanned spacecraft have revealed smoke plumes hundreds of miles high. Unlike Callisto, these volcanos are constantly changing the surface of the planet.

**Period:** The amount of time it takes for a planet to complete one revolution, or one orbit about the sun.

## Useful Websites

Galileo Mission to Jupiter:

<http://www.jpl.nasa.gov/galileo/education/teacherres.htm>

Windows to the Universe: Tour to Jupiter:

<http://www.windows.ucar.edu/tour/link=/jupiter/jupiter.html>



# Investigating Jupiter and its Moons: Part Two

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Adapted with permission from *From the Ground Up!*

## Goals

- Evaluate and revise their existing ideas about the motion of moons based on patterns seen in data (images)
- Learn how to create animations using MicroObservatory Image software

## Activity Overview

The youth will create an animation from the images they took in Part One and compare it to their previously generated model, considering what their model accurately represents and what it does not when compared to real observations.

## Background

Please refer to the background information in the first part of this activity.

## Preparation

Space Required: Computer Lab

Materials:

- A computer for every 1-2 participants
- MicroObservatory Image software installed on each computer
- The Observation Log Sheet from the previous activity
- Models from the previous activity
- Chart paper (or white board)

Preparation time: ⌚ ⌚

Activity time: 60 minutes.

#### Gathering of materials and final preparations:

A few days before you facilitate this activity, take images of Jupiter and its moons yourself. Save a complete set of 4-6 images (taken by you or the participants) and print several sets of them black on white. You will use these sets for the initial discussion (reflecting on images). Make sure you create an animation with your own images: by doing that you will be better prepared to assist participants during their work.

Review the definitions of the astronomy terms in the vocabulary section at the end of the previous activity.

## Procedure

#### Discussion lead-in:

With the models from the previous activity displayed, remind the participants of their work with the Jupiter images from the previous activity. Have them briefly recall what their models predicted.

#### Creating a Jupiter animation

1. Have the participants download their images of Jupiter from the previous activity and save them to a single appropriately named folder.
2. Participants should rename their files “1.FITS,” “2.FITS,” “3.FITS,” etc. in chronological order from oldest to newest. Both Windows and Mac OS will order the images appropriately when the files are left with their default names and sorted alphabetically.
3. Have participants open their files in MicroObservatory and check to see that all the images came out. Close any images where the planet and moons are not visible.
4. Have participants select **Process -> Adjust Image** and use the “Auto” tool with the “Linear” radio button selected on each of their images.
5. Have participants click on their images in reverse order - “3.FITS,” “2.FITS,” “1.FITS.” This step organizes the order of the frames in their animation.
6. Have participants select **Process -> Stack -> Convert** images to stack.
7. Using the arrow buttons at the bottom right of the resulting windows, have the participants scroll through each of their frames. Jupiter will most likely seem to “jump” from place to place. This indicates that the images need to be “aligned.”

8. Have participants select **Process** -> **Shift**. They will select a single image as the “background” frame and select another image for the “foreground” frame. The foreground frame is layered over the background frame and made slightly transparent.
9. The youth should align the foreground frame’s picture of Jupiter against the background frame. The participants should disregard the positions of the moons. This step is repeated for the remaining images by selecting each one as a foreground frame and repeating the alignment procedure. Click “OK” when done.
10. Have the participants scroll through their frames again using the arrow keys. If they have aligned their images well, Jupiter will not appear to jump. If there are any obvious errors, they should repeat the previous step.
11. Have participants select **Process** -> **Stack** -> **Animation** options and enter a value of “12” in the “Frames Per Second” field. They should then click “OK.”
12. Have participants select **Process** -> **Stack** -> **Start Animation** to view their work. Selecting **Process** -> **Stack** -> **Stop Animation** will stop the new clip.
13. The frame rate and alignment of images are still editable when the animation has stopped. Participants may revise these if an image is obviously out of alignment or if a different framerate may be more comfortable to watch.
14. Select **File** -> **Save as** -> **Animated GIF** and name and save the file normally.
15. Animated GIF images may be opened in a web browser, even where internet access is not available.

#### Testing the model

1. The youth should observe their animation and note the motion of the “dots.”
2. Have the youth compare their models with the animation they have just created.
3. Ask the participants if they can recreate the motion of the “dots” in the new animation.

4. Discuss the models. Were the models an accurate representation of this system? Explain why. What was shown accurately and what wasn't? How could they be improved?

## **Follow up**

Jupiter and its moons are much like a tiny solar system themselves. The system is a rich topic for further investigation for individual and small group projects.

## **Watch out for...**

- ❑ The fifth step in creating the animation can be a significant source of frustration. At the time of this writing, MicroObservatory Image lacks a good interface for arranging the frames of an animation in sequence. Managing more than a few frames can clutter the workspace and become difficult and a carefully ordered series of images can be undone by clicking on another image without thinking. As such, a systematic methodology is demanded. All image processing should be completed before any attempt to sequence the images is made. One approach to make the sequencing step more intuitive is to have the youth drag the windows into “piles,” rather than just clicking on them. If an image is accidentally selected, its window rises to the top of the pile, making it obvious that the order needs to be repaired.
- ❑ It is important that when shifting their images, the youth center each frame on Jupiter. If the sequence is aligned to a specific moon, the other bodies will appear to orbit it rather than the planet.

## **Vocabulary**

Please refer to the vocabulary words from the previous section.

# Advanced Image Processing

---

Adapted with permission from *From the Ground Up!*

## Goals

- ❑ Learn about color tables, noise reduction and other advanced image processing tools
- ❑ Gain a greater understanding of how images can be manipulated to show information about the light received by the detector

## Activity Overview

Participants will experiment with the different color tables in MicroObservatory Image and learn to use an image taken with the “opaque” filter to remove background noise from an existing.

## Background

**False Colors:** The colors we see in the world around us are the result of the way that the human eye and brain perceive different wavelengths of light in the visible part of the electromagnetic spectrum. A CCD camera attached to a telescope however “sees” differently from the human eye. A main difference is that the CCD is usually color-blind, i.e. it only records white, black and shades of gray depending of the intensity of the light that falls on the CCD. It is possible to produce real color images of astronomical objects. We will learn how to do so using color filters and image processing software. Image processing software allows us also to create what are sometimes called "false color images." That is because the colors used to make them are not "real" but are chosen among a selection of “color tables” to bring out important details. The color choice is usually a matter of personal taste, and is used as a type of code in which the colors can be associated with the intensity or brightness of the light from different regions of the image.

**Background Noise:** Since astronomical CCDs are designed to image faint objects they must be extremely sensitive even to small amount of light (or small number of light particles). One drawback to this sensitivity is that the detector also picks up light particles generated by heat within the camera. To minimize this effect, astronomical CCD cameras are equipped with cooling systems. These systems are capable of lowering the camera's operating temperature 20 to 60°C (about 40 to 100°F) below ambient temperature. Even this though is not enough to remove all the extra photons produced by heat within the camera. These unwanted photons are called background noise. What does “background noise” look like? When you take a digital image with a CCD detector, like the one used for MicroObservatory, you can notice some (or many) little white dots in your image that are NOT stars: If the dots are a single pixel ("picture element") wide, they are likely to be background noise. We call these pixels "hot pixels". To be able to get rid of the background noise, CCD detectors can be used to take a dark frame. A dark frame is an image taken with the camera's image sensor covered. This image detects only the background noise. Image processing software then allows you to subtract the dark frame from the original image to obtain a much clearer image (with much less noise).



Image of Andromeda taken using a “Clear” filter (i.e. using no filter at all): The image recorded both the signal (light) from the object and the noise produced by the detectors electronics.

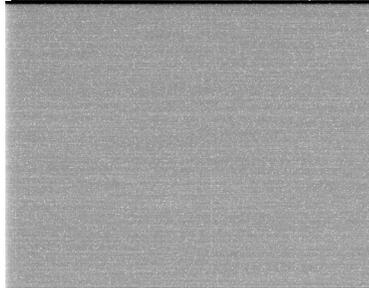


Image of Andromeda taken using the “Opaque” filter (i.e. with the camera’s shutter closed). The grey and white squares on the images are called “hot pixels.”

## Preparation

Space Required: Computer Lab

Materials:

- A computer for every 1-2 participants
- Image-processing software: MicroObservatory Image on every computer

- ❑ A copy of the Observation Log Sheet per participant

Preparation time: ⌚ ⌚

Activity time: 60 minutes.

#### Gathering of materials and final preparations:

In preparation for this activity remind the participants to take images of their favorite objects. However they will have to take two images of their object each time: one image using the “Clear” filter and one image using the “Opaque” filter. It is important that the exposure time used for both images is the same.

Prepare a few sets of images of the same object taken with the “Clear” and “Opaque” filters to have ready in any case. You can find many of these sets in the Image Archive Directory.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during the activity.

## Procedure

#### Discussion lead-in:

Remind participants that the image they display on their screen when they open it with MicroObservatory Image is made up of thousands of pixels. Each pixel is associated with a number that says how many photons of light were gathered by the camera in that area of the image, just like in the “From Pixels to Image” activity. They can see this by themselves when they put the cursor on the screen: the dialogue box in the upper right of the screen shows the coordinate of the pixel the cursor is on and a number corresponding to the number of photons collected by that pixel. They will now change the contrast of the image and apply color tables, just as they did in the “From Pixels to Image” activity.

#### Downloading and opening an image.

1. Have participants save 3-4, or at least two, of their good images in FITS image format.
2. Use the MicroObservatory Image application, which should already be on your computer. Go to File and select Open image on local disk. Then choose the file you want to open. The image will open in a new window.

#### Adjusting the image display.

Have participants go to the **Process** menu and select **Adjust Image** and change the brightness and contrast as desired.

#### Giving false colors to the image.

1. Have participants go to the **Process** menu, select **Color Tables** and any of the options available there. They should keep adjusting the image (Adjust Image box) until you are satisfied with the quality of the image and the amount of detail that you can see the image.

*What happens to the image?*

2. Instruct the youth to go to the **File** menu and select **Save As** and **GIF** within the submenu. When the dialogue box appears, they should label their files so that you can remember the color table used for each image.

#### Comparing the images.

After the participants have saved the false color images, ask them to open one of the color images and its original black and white version side by side on their computer. Ask them to compare the images and discuss the answers to these questions:

*Which image do you like most? Why?*

*Which image seems to help you see most details in the image? Why?*

*What details can you see?*

#### Removing the background noise.

Have participants choose a set of images taken with the “Clear” and “Opaque” filters of the same objects. Have them open both images next to each other with MicroObservatory Image. Instruct them to click on the image taken with the “clear” filter. Under the **Process** menu, they should select **Image Calculator**. In the resulting dialog window, they will now subtract the image taken with the “opaque” filter from the image taken with the “clear” filter. To do so the image taken with the clear filter must be selected as **Image 1** and **Image 2** the image taken with the “opaque” filter. As for Operation make sure to change “add” to “subtract.” When all is set (it is advisable to click on “create new window” so that the new image will open in a new window) they should press “OK.” A new window will open (named “untitled”): the image in this window is the original “clear filter” image with the information from the “opaque” image, containing mostly “noise,” removed.

## Follow up

The Hubble Site has a great tutorial about color imaging ([http://hubblesite.org/sci.d.tech/behind\\_the\\_pictures/](http://hubblesite.org/sci.d.tech/behind_the_pictures/)). Using some of the best images we have seen from Hubble Space Telescope the tutorial explains how color is used in the following ways:

- To depict how an object might look to us if our eyes were as powerful as a telescope, or as the Hubble Space telescope itself
- To visualize features of an object that would ordinarily be invisible to the human eye
- To bring out an object's subtle details

This tutorial is a must read and play (great interactive tools) to learn and enjoy using color with MicroObservatory imaging.

Encourage the participants to take images with the opaque filters in particular when they will start taking images using the three color filters to create RGB images. In that case they will have to subtract the image taken with the “opaque” filter from all three images that they will then combined in the RGB image.

## Watch out for...

- Make sure that participants understand that the choice of a color table needs to meet at least two criteria: to please our personal taste (a very good reason to choose a color scheme instead of another) and to help our eye to see details better (for example, these might be details on the surface of the moon or details about the illumination of the surface itself).
- Make sure that participants subtract the image taken with the “opaque” filter from the actual image of the object and not vice-versa.
- Make sure that participants change “add” to “subtract.”
- Images taken with the “opaque” filter should be taken very close in time to the actual image of the object and the exposure time needs to be the same.
- The product of the subtraction is a new image and the scale on “Adjust Image” changes dramatically. Participants will need to adjust the value of the scale again (just hit “auto”) to best view the image.
- Be prepared to explain to the youth that the subtraction of the dark frame does not remove all the background noise. However the new image should look improved.

## Vocabulary

**CCD:** CCD stands for charge-coupled device. A CCD is a detector made on a silicon wafer. Due to the physical nature of silicon, photons of light that hit it generate electrons in the silicon. The job of the CCD is to collect these electrons in its "light buckets" (called pixels) during the length of the exposure to light. The more light falling on a particular "light bucket" or pixel, the more electrons that pixel will contain. The buckets then transfer their electrons (think "water bucket brigade") out to the CCD controller (which contains the electronics to control the CCD) and on to the computer. The computer then regenerates the image.

**dark frame:** A dark frame is an image taken with the CCD's shutter closed. This image records only the electronic noise due to the detector itself. When a picture is taken of the night sky it records both the object in the sky as well as the noise. The dark frame is subtracted from this image to leave only a clear image of the object.

**electromagnetic spectrum:** The full range of frequencies, from radio waves to gamma rays, that characterizes the different "colors" of light. There is a relationship between the amount of energy electromagnetic radiation (light) carries and the frequency. Radio waves are low frequency and low energy radiation while gamma rays at the other end of the spectrum are high frequency and high energy radiation. Visible light, that our eyes can see, is also part of the electromagnetic spectrum.

**opaque filter:** This is not a real filter. When using MicroObservatory you select "Opaque" in the filters selections when you want to take an image with the camera's shutter closed.

## Useful Websites

Hubble Site - Behind the Pictures:

[http://hubblesite.org/sci.d.tech/behind\\_the\\_pictures/](http://hubblesite.org/sci.d.tech/behind_the_pictures/)

In astronomy imaging we often use color as a tool, whether it is to enhance an object's detail or to visualize what ordinarily could never be seen by the human eye. Learn how scientists that work with images of the Hubble Space Telescope do that (we follow the same process to create color images with MicroObservatory)

Guide to CCD Imaging: <http://www.starizona.com/ccd/>

This website is designed to teach you how to take CCD images and to process them to achieve impressive results. It is also intended to be a showcase of CCD imaging to inspire you to head out under the stars and capture beautiful pictures! Advanced.

Astronomy Picture of the Day: <http://antwrp.gsfc.nasa.gov/apod/>

# Group Portrait of the Universe in Color: Taking Images

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Adapted with permission from *From the Ground Up!*

## Goals

- Take images and gather information needed to accomplish the color “group portrait” task using the MO interface
- Practice using the MicroObservatory telescope interface efficiently as a tool to gather data.

## Activity Overview

In teams, participants will take images using MicroObservatory’s three color filters (red, green, and blue) in preparation for assembling them into a single full color image in the next activity.

## Background:

The human eye can sense red, green, and blue light. Combinations of these three colors are perceived as full-color. Any color scene can be separated into its red, green, and blue components and then reconstructed to form full color. When creating an image, scientists may have to make choices about what to display, and these choices may affect the interpretation of the image.

The universe tells us its story largely through the light that it sends us and color plays a key role in the story. To the eye, most of the objects in the night sky look white, except for the planet Mars and a few stars, such as Antares, whose reddish glow is noticeable if you look carefully. But through a telescope, the universe is aglow with color. What can these colors reveal?

### **Colors reveal temperature**

Stars that are cooler glow red, while medium-hot stars like our Sun glow yellow, and very hot stars glow a bluish-white. In fact, *all* objects at the same temperature will glow with the same color. The ceramic pots in the kiln, heated to a temperature of several thousand degrees, are glowing with same dull red color as a star at the same temperature halfway across the universe. If we could heat the pots just a thousand degrees more, they would glow with a yellow like the Sun.

### **Colors reveal chemical composition**

Every chemical element absorbs and emits light at sharply defined wavelengths which are characteristic of that element. Neon, for example, emits the warm orange light familiar from neon signs. Chemical elements in the Sun absorb specific wavelengths of sunlight passing by; the Sun's spectrum is darker at these wavelengths. By matching the pattern of these lines to known patterns from laboratory experiments, astronomers can tell which elements are present in stars and other objects, and in what amounts.

### **Colors reveal motion**

The Doppler Effect is a phenomenon that applies to sound waves in which the pitch of a sound emitted by a moving object changes. We observe this change in passing sirens and train whistles. Similarly, there is also a shift in the color of an object moving towards or away from us. On Earth, there are no objects that move fast enough for their colors to perceptibly change, however many objects in space do.

## **Preparation**

Space Required: Computer Lab

Materials:

- A computer for every 1-2 participants
- Observation Log Sheet for each participant

Preparation time: ⌚

Activity time: 30 minutes

Gathering of materials and final preparations:

Make copies of the *Suggested challenges for color photographs* table from the appendix.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during the activity.

## Procedure

Discussion lead-in:

Ask participants how they could make a full-color image of an object using color filters. Take note of the answers on the blackboard.

Have participants discuss with their team what kind of object they would like to image. Remember that large objects such as nebulae often form the best subjects. Planets may not be good choices, because they are small and will show little color variation in the MicroObservatory telescopes.

Have each team develop an outline for how to proceed. They will be able to use:

- The telescopes
- The telescopes' filter wheel, containing filters that pass red, green, and blue light
- MOImage software for combining the red, green, and blue information to form a color image

### Taking Images

1. Participants work in teams of three. Have each team select a celestial object they would like to image, using either the list of suggestions provided, or another target. It does not matter if several teams image the same object, since they will be able to compare their results.
2. Make sure that participants understand they have to take three images for each celestial object: one each through the red-, green-, and blue-passing filters.
3. To ensure that they produce successful images, help participants with these issues:
  - Make certain that the targets they have chosen are visible in the night sky at this time of year: remind them to use the “What’s Up” feature on the MicroObservatory menu.
  - When given a range of exposure times for a chosen object, encourage participants to take images using several exposure times within the recommended range for their object.

## Follow up

In the next session participants will learn how to combine black-and-white images taken in the three color filters to create a full-color image.

## Watch out for...

- ❑ Sometimes participants duplicate the use of a filter or forget to take an image with one altogether. The log sheets are especially helpful in this activity. Make sure participants fill out their logs *as they submit their requests* and record what filter they use. Have teams double-check each other's work.
- ❑ Similarly, it's possible that a needed image may not come out for reasons beyond anyone's control. If possible, a good preventative measure is to have participants take extra images on different telescopes.

## Vocabulary

**color filter:** A sheet of dyed glass, gelatin or plastic, or dyed gelatin cemented between glass plates, used in photography to absorb certain colors and transmit others. The filters used for color separation by MicroObservatory are red, green and blue (RGB).

## Useful Websites

The Science of Light: Light is everywhere in our world. We need it to see: it carries information from the world to our eyes and brains. Seeing colors and shapes is second nature to us, yet light is a perplexing phenomenon when we study it more closely.

<http://www.learner.org/teacherslab/science/light/>

Light and Color: A more technical background on light and color

<http://www.fi.edu/color/>

# Creating Color Images

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Adapted with permission from *From the Ground Up!*

## Goals

- ❑ Learn how to combine RGB color-filtered images into a full-color image
- ❑ Reflect on their existing ideas about the color of objects in the universe and revise them based on their experience creating color images

## Activity Overview

Participants will create their first full-color pictures from black-and-white white images taken through color filters, using a familiar example of a flower as a subject, a nebula, and their own images from the previous activity.

## Background

Taking color pictures with Earth and space based telescopes is much more complex than taking color pictures with a traditional camera. For one thing, these telescopes don't use color film - in fact, they don't use film at all. Rather, their cameras record light with special electronic detectors. These detectors produce images of the cosmos not in color, but in shades of black and white.

Finished color images are actually produced by combining two or more black-and-white exposures of the same object. Each exposure has been given a different color during image processing and then the images are combined.

The colors of these images, which are assigned for various reasons, are not always what we would see if we were able to visit the imaged objects in a spacecraft. We often use color as a tool, whether it is to enhance an object's detail or to visualize what ordinarily could never be seen by the human eye.

# Preparation

Space Required: Computer lab

Materials:

- Computer for every 1-2 participants
- MicroObservatory Image 2.0
- Images of sunflower taken through color filters
- Images of Orion Nebula taken through color filters
- Images taken by participants from previous computer activity

Preparation time: ⌚ ⌚ ⌚

Activity time: 1 hour

Gathering of materials and final preparations:

Make an extra effort to familiarize yourself with the nuances of the process outlined in this activity. The skills developed here are among the most important developed in the image processing software.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during the activity.

# Procedure

Discussion lead-in:

Ask the participants to summarize some of the skills they have developed in MicroObservatory Image. This activity represents a culmination of the image processing techniques covered before. Explain that they will be assembling color images from the seemingly black & white data they received when taking their exposures with the color filters. Stress that this process is the one used by professional astronomers in creating the brilliant pictures of faraway objects with which they are familiar.

Sunflower Color Image:

1. Have the participants locate the files with the three black-and-white sunflower images that you previously downloaded.
2. Have the participants launch the MicroObservatory Image software on their computers.
3. Tell the youth to open *flowerR.gif*. This is the red portion of the full color flower image. Under the **Process** menu, have them select **Color Tables** -> **Red**. This automatically colors the image red. In the same

manner, have them open the other files, *flowerB.gif* and *flowerG.gif* and color them appropriately using the same steps

Under *the Process* menu, they should select **Stack**, and select **Convert Images to Stack**.

4. Have participants take a moment to scroll through the stack, using the arrows at the bottom edge of the image. Note that the three images contain very different information about the picture. The third image is very dark, because there is no blue in the scene, except for the sky.
5. To create the color picture, go to the **Process** menu, select **Stack**, then **Convert Stack to RGB** (which stands for red, green, blue color). The result should be a full-color picture of the sunflower.  
If participants mix up the color of the images, for example, by coloring the red-information image green, they will get a strangely-colored picture that won't be the color of the original image.

#### Orion Nebula Color Image:

We are now ready to use the MicroObservatory telescopes to create a color image of an object in the night sky. Model the process using FITS images of the Orion Nebula that you previously downloaded as they follow along.

1. Explain to the participants that when the telescope has taken the images and posted them on the Web, they need to download the three images in FITS format.
2. They should be sure to name their files clearly so they know which image was taken through which filter (e.g., "orionRed.FITS"). The filter color is listed in the Image Info file and FITS header (under **Windows -> FITS Header**) that comes with each image.
3. **Opening the three images.** Ask the youth to launch the MicroObservatory Image processing program on their computers and open the image taken through the red, green, and blue-passing filters. Under the **Process** menu, ask them to select **Adjust Image**. When the Adjust Image window opens, select the **Auto** button to get a good first look at the image.
4. Instruct the participants to make further adjust the brightness and contrast for each image, as is necessary. The purpose is to make a good representation of the image.
5. **Coloring each image red, green or blue.** Working with the red-filtered image first, have participants click on the **Process** menu and select **Color Tables -> Red**. Their images will turn red. Then work with the green-filtered image, selecting **Process -> Color Tables ->**

**Green** to turn the image green. Finally, color the blue-filtered image blue.

Explain to the participants that the areas in the original scene that had a lot of red became the *brightest* areas in the red-filtered image. In turn, these bright areas in the red-filtered image will become the *reddest* areas in the final image. The same holds for the green and blue-filtered images.

6. **Aligning the images.** Each of the images will most likely be slightly out of alignment. They will need to be aligned, or “shifted” so that when they are combined the result won’t be blurred. Under the **Process** menu, have the youth select **Shift**. As prompted, they should select one of your images as the background image over which they will shift (i.e. align) the other two images. The red image usually makes the best background. Then have them select a “foreground.” (You should see the background image through the slightly transparent foreground image.)

Using the mouse keys and the I, J, K, and L keys as prompted, have participants align the two images. Once satisfied with the alignment, they should select the remaining image as the foreground and align it against the same background as well. Once this is done, they may click the “Okay” button.

7. **Stacking the images.** Under the **Process** menu, have participants select **Stack -> Convert Images to Stack**. They can flip through these images using the arrow keys at the bottom right of the new window to see them individually and check that they are well aligned.
8. **Creating the final color image.** Under the **Process** menu, have participants select **Stack -> Convert Stack to RGB**. The program now merges the three red, green, and blue images to create the final image.
9. **Saving the final image.** Have participants make sure to save their final images as GIF file and label it with a clear filename.

#### Participants’ Color Images

1. Have participants download the *three* images of their target that you took using color filters - one each using the red-, green-, and blue-passing filters.
2. Have participants download the three images in FITS format. Tell them to name the files clearly so that they know which image was

taken through which filter (e.g., “MyTargetRed.FITS”). The filter color is listed in the Image Info file.

3. Follow steps 3 to 19 above.

Make sure that participants take new images with MicroObservatory using the color filters to create new color images.

### Discussion

Reflecting on the results the obtained in this activity is very important. If possible, while participants are working on their images, engage 2-3 of them at a time in a conversation using some of the following questions. Alternatively you can engage the whole group in a general discussion on the results of their activity following these questions:

*Does the color of the object in your image tell you anything about the object? What?*

*The telescope's light sensor is not equally sensitive to red, green, and blue light. How might this affect the color of your final image?*

The telescope's light-sensing silicon chip is *most* sensitive to red light, and *least* sensitive to blue light. This means that reddish objects will appear comparatively brighter than bluish objects in your black-and-white images. And when you reconstruct the color scene, the final image will appear redder than the actual scene in nature.

*When you added the three images together, did you boost the brightness of any of the images? If so, how did this affect the color image?*

It's possible to compensate for the lower sensitivity in the blue if desired by boosting the brightness of the image taken through the blue-passing filter. This can be done when adjusting the image's contrast, just before colorizing the three black-and-white images.

*How closely do you think that your image captures "reality" -- and why?*

Astronomers try to learn as much as they can from the images they take. This does not always mean producing an image that most closely resembles what you would see with your eyes. For example, by enhancing the contrast of a scene, you can bring out details of the image you might never have noticed if you produced the most natural-looking image. Scientists sometimes alter the color of their images for

the same reason: to bring out details that might otherwise be missed.

*How would you determine the best color balance, or the best image processing?*

## Follow up

Participants should continue to take images with the filters and assemble them into color images. This skill is frequently used in developing projects utilizing the MicroObservatory telescopes and software.

## Watch out for...

- ❑ As participants carry out this activity, they must make a decision that faces astronomers every day: whether and how much to "boost" the red, green, or blue images before combining them. The decision will affect the color of the final image. You might think that to get accurate color in the final image, each of the three component images should be processed in exactly the same way. However, the telescope's light-sensing chip is less sensitive to blue than to red light. Therefore the blue image will generally be fainter than the red and green images; it will need to be brightened during image processing, relative to the other images. Also, the three color filters do not pass equal amounts of light. This also will affect the accuracy of the color in the final image. Although it is not necessary to correct for these factors, participants should be aware that the color of their final product may not be an accurate rendition of the scene. In fact, in much of astronomy, *there is no such thing as "true color,"* because the astronomer must make unavoidable and sometimes arbitrary choices about how to display the image.
  
- ❑ When combining filtered images, MicroObservatory Image will report an error message if the user has extra images open. When selecting "convert images to stack," an error prompt will read, "All slices must have the same width, height, and bit depth." The problem may also be caught when selecting "convert stack to RGB," where the prompt will say, "You need one red, one green, and one blue slice to make an RGB image! Use the Color Tables menu item to do this." Simply close the extra image to remedy the problem. If a stack has already been made, the user may select "convert stack to images."

## Vocabulary

**silicon chip** : A wafer-thin slice of silicon that contains thousands of microscopic electronic circuits.

## Useful Websites

Hubble Site: Behind the Pictures:

[http://hubblesite.org/sci.d.tech/behind\\_the\\_pictures/](http://hubblesite.org/sci.d.tech/behind_the_pictures/)

The Hubble Space Telescope is noted for providing beautiful and often bizarre color pictures of galaxies, planets, and nebulae. Do the pictures really reflect the colors these objects would have if we visited them in a spacecraft? Find the answer by peeking behind the scenes — a look at how Hubble actually makes images.