



Explore the Universe with A Robotic Telescope

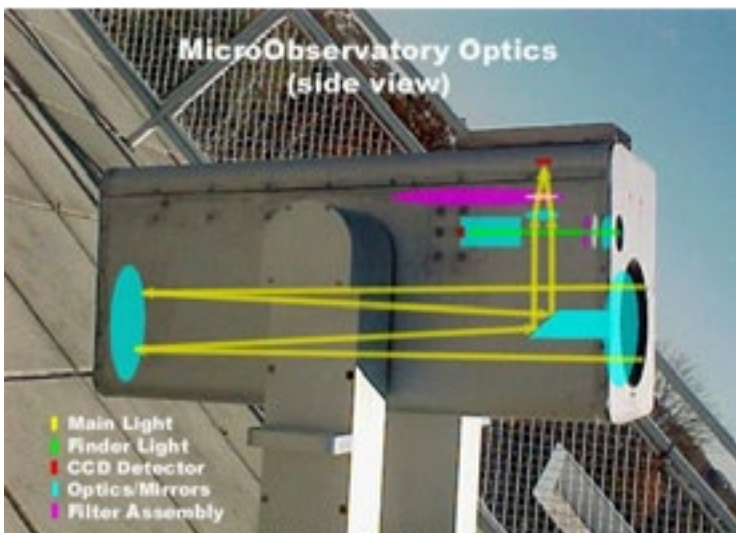
You and your program participants are about to control a powerful astronomical instrument from your own computers! Just like professional astronomers, you will send commands remotely to telescopes that will take images of planets, nebulae, galaxies, and more. While using MicroObservatory, users like you can be actively involved in posing questions, designing investigations, gathering evidence, and interpreting your own results as you explore the universe.

ABOUT MICROOBSERVATORY

MicroObservatory is a network of robotic telescopes that can be controlled over the internet. The telescopes were developed at the Center for Astrophysics | Harvard & Smithsonian and are designed to enable a nationwide audience of learners to investigate the wonders of the deep sky from their own computers, tablets, or even cellphones! The telescopes are located and maintained at observatories affiliated with the Center for Astrophysics, including locations in Cambridge, MA, Amado, AZ, and Coquimbo, Chile.



Each of the 5 instruments in the network is a 3-foot-tall reflecting telescope, with a 6-inch opening (aperture) at the front and a 6-inch mirror at the back to capture and focus the light from distant objects in space. Instead of an eyepiece, the MicroObservatory telescopes focus the collected light onto a CCD detector (an electronic chip like that in a cell phone camera). This digital detector records the image as a picture file composed of 650 x 500 pixels.



Users operate the MicroObservatory telescopes and download their images themselves, with no human intervention in the loop. They choose targets, select exposure times, color filters and other parameters. Users can access the telescopes via the MicroObservatory website anytime during the day, and their

image requests will be automatically taken that night without depending on a telescope operator or other outside "experts."

FEATURES OF ONLINE TELESCOPE EXPLORATIONS

MicroObservatory enables users to have a personal experience with the process of science through the collection, processing, analysis, and interpretation of their very OWN data. Through these unique investigations you are able to explore the universe for yourself.

◇ **Investigations can be authentic and open-ended**

Investigations are motivated by open-ended questions that make contact with both the user's curiosity and the cutting edge of science. Learners are able to see how the basic concepts of science can be applied to solving real questions of interest.

◇ **Qualitative and quantitative possibilities**

Using MicroObservatory, users can explore the universe both qualitatively and quantitatively. Through activities from general observation to measuring distance to determining variability through graphing users have a variety of experiences available to them to practice scientific skills.

◇ **Opportunities for reflection and interpretation**

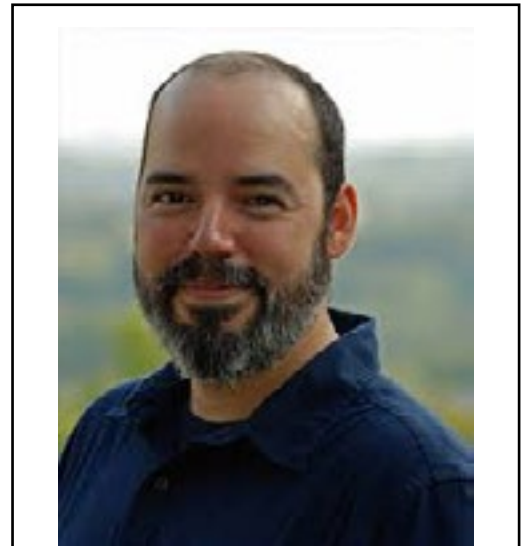
Science is not a collection of disconnected facts. It is a dynamic process that begins in curiosity and continues with a search for meaning. We suggest allowing time to reflect on what and why you are investigating, and to interpret your results in a context meaningful to you.

◇ **Focus on scientific practices**

It is often said that you have to do science in order to learn science. However, a major challenge is to focus on those inquiry skills that will be of lasting importance. Learning to use software that may not even exist in a year or two is not as important as learning how to design an investigation, or how to estimate, or how to interpret results. MicroObservatory telescope activities seek to minimize routine work, allowing more time for self-guided and designed investigations.

◇ **Independent projects**

Because the MicroObservatory telescopes and image archive are easily accessible, there are many opportunities for additional projects. Once you have gained familiarity with how to use the telescopes and how to work with the images, the sky is the limit for independent projects.



Meet Dr. Rudolfo Montez. Dr. Montez is an astrophysicist with NASA's Chandra X-ray telescope. He makes requests for images from the Chandra telescope through his computer, just like you'll be doing with MicroObservatory.

BEST PRACTICES FOR USING MICROOBSERVATORY WITH LEARNERS

Based on years of co-development with educators and program facilitators using the telescopes and activities, we recommend the following approaches and techniques when using the MicroObservatory Telescopes to support learning:

Model the use of the telescopes with learners first. If you have a projector, it is ideal to demonstrate with learners how to access the telescopes and access the images.

Have learners work in teams. This allows students to discuss ideas important to the investigation.

Allow time for learners to predict, plan, and reflect. These are integral parts of using the MicroObservatory telescopes to gain confidence with scientific practices.

Manage projects. Make certain that learners understand how to use the telescopes before they begin independent projects. Otherwise, you will be overwhelmed by individual questions once they begin.

Set aside room on the computer. Program participants will be downloading many processed images from the telescope. Decide ahead of time how you would like them to store these files on your computers. For example, you may want to set up one or more folders to keep learners' work separate from other projects that share space on the computer.

Try out the telescope and activities yourself. Before using MicroObservatory with learners, make sure that you have successfully taken images with the telescope, and have tried possible activities.

You may wish to print out separate copies of the next several pages for you and your participants to refer to when you first begin using the telescopes.

GETTING READY

Follow these easy steps and you'll be ready to use the MicroObservatory telescopes in no time!

What you'll need. Here is the minimum that you'll need to get started:

- **Computer(s) or other devices with access to Internet (a tablet or larger screen is recommended)**
- **Browser to access JS9-4L image-processing software (we suggest Chrome or Firefox)**
- **Printer (optional)**

ACCESSING THE TELESCOPES AND TOOLS

The **Observing with NASA Portal** is freely available to anyone with a valid email address, and can be accessed at the MicroObservatory Splash Page at this URL: <http://www.microobservatory.org/>

The MicroObservatory Splash Page is the hub to access all MicroObservatory interfaces. Here you'll find the *DIY Planet Search* portal, where you yourself can detect planets around other stars using images from the MicroObservatory telescopes. This page is also home to the *YouthAstroNet* portal, where educators of young people ages 9-14 can join an inclusive online learning community, and the *Full Access Legacy* portal where MicroObservatory partners can obtain further telescope access.

Access JS9-4L, our image-processing software

To get the most out of your telescope images, you will need to use image-processing software. The MicroObservatory Image Processing Software (JS9-4L) can be accessed directly at this web site: <https://waps.cfa.harvard.edu/eduportal/js9/software.php> - no software downloads are required.

The image processing software opens with a lightbox tour to walk you through the basic processing steps. There are also video and written tutorials available to guide you through the process.

TAKING AN IMAGE

Important general information

You control the telescope yourself, with no human intervention in the loop. Therefore, you must tell the telescope how you want it to take an image. Normally, you access the telescope site anytime during the day and request that your image be taken that night; to do this go to the *Observing with NASA Portal* (<http://www.microobservatory.org>).

After the telescope takes an image, it e-mails you an alert when your image is ready. The email contains links to where your image is posted in the MicroObservatory Image Directory. [To access the Image Directory directly, go to this URL: <https://waps.cfa.harvard.edu/microobservatory/MOImageDirectory/ImageDirectory.php>]

What you'll need to request an image

You'll need an email address to request your MicroObservatory image. Make sure you have it handy, and know how to access your inbox before getting started.

There are a number of different telescope targets from which to choose every night. As you proceed through your request the portal will guide you through choosing appropriate telescope settings.

◇ Choose your target

The telescope page separates target options by their location in space, or "cosmic address." First the Moon, planets, and other nearby objects in our Solar System, then stars and nebula within our Milkyway Galaxy, and finally other galaxies in the Universe. Select the "Observe" button for the target you wish to image.

◇ Select "main camera," "finder camera," or "zoom camera"

You will normally use the telescope's main camera, which has a field of view of almost one degree. On occasion, you may choose to use the finder scope, which has a field of view of about ten degrees, or the zoom camera, which has a field of view of a half of a degree.

◇ Choose exposure time

The site will guide you toward choosing the recommended exposure time for each various target listed. Remember, dim objects will need more time for light to be collected.

◇ Select a filter

The default selection is "clear filter" which lets all wavelengths of light through to the detector. For very bright objects such as the Moon, you must use a grey filter (called a "neutral density" filter). This filter reduces the light that reaches the camera by a factor of 10⁴ (10,000). The color filters (Red, Green, and Blue) are generally used to create color images, also known as RGB images. They only let specific wavelengths of light through to the detector. Different targets may have different filter option available

◇ Select the "Continue" button when ready

Once you fill in your contact information on the next screen and hit submit, a screen will automatically appear to confirm your requested target and telescope settings. If you have forgotten any required information, the screen will prompt you to re-enter it. Your request is now in the queue for that night's observations - one or more of the MicroObservatory telescopes will observe your target that night, and the next day you will receive an email with a link to your image.

RETRIEVING YOUR IMAGE

After the telescope takes your image, it will e-mail your account to alert you. You can access your image directly from your e-mail, by clicking on the link to your specific image file, which you will see listed. Alternatively, you can copy and paste the URL from the email into your browser.

Every image posted on the MicroObservatory Image Directory also has a link to an “Info” page that contains information about the image, including the exact time it was taken, the location of the telescope, exposure time, etc. The image remains in the Directory for three weeks, and is then deleted.

SPECIAL NOTE: If you wish to keep your unprocessed image, you should download the raw “FITS” file from the Directory to your own device.

Retrieving Others Users’ Images

You can also look at (and download) the images taken by all other MicroObservatory users:

Access the Image Directory page

All recent images taken by the MicroObservatory telescopes are automatically posted on the website’s Image Directory page, at this URL:

<https://waps.cfa.harvard.edu/microobservatory/MOImageDirectory/ImageDirectory.php>

The images you will see listed are those taken within the last 10 to 30 days.

Find a specific image file

The image files for all users are listed in the order of when they were taken (most recent images at the top). To help find a specific image, you can use the “Select Object” pull-down menu, or sort the list by target object filename, telescope, filter, or date taken. To sort the list, click on the appropriate column heading above the list.

Examine your image

The MicroObservatory website stores two different versions of your image. The main link to your image file within your email allows you to view the GIF-format version of your image in your browser. This version will be satisfactory for images of the Moon, planets, or other very bright objects. For fainter objects such as galaxies and nebulae, you will need to look at the raw FITS- format version of your image. The FITS-format (the standard image format used by professional astronomers) contains all the original information in your image—more than you can see in the GIF-format version. You should always use the FITS- format image if you plan to process your image, or make measurements from the digital file.

The FITS-format images cannot be viewed on your desktop, or within typical image editing applications such as Adobe Photoshop. They must be opened in an application that allows you to view FITS-format images, such as the free, MicroObservatory Image Processing Application, JS9-4L. You can open your image in JS9-4L by clicking on the JS9-4L link in the Image Directory, or by downloading your image and using the Image Open option in JS9-4L.

View the image thumbnail and Image Info page

Every MicroObservatory image is accompanied by a link to its “Image Information” page. Click on this link to see all the information about how and when your image was taken. For some telescope activities, you will want to know when the image was taken, or what telescope settings were used, or what the exposure time was. This information can also be accessed when viewing your image in the JS9-4L software.

Download your image

If you would like to be able to access the FITS-file of your image beyond the 30 days it is available in the Image Directory you can download it by clicking on the FITS Image Icon in the directory. You can also click on the Image File name, and follow the directions to download there.

Save and name your image file

The name of your image file contains the first few characters of the name of the target, followed by a string of 12 digits that tell you exactly when the image was taken (mo da yr hr min sec, in the format MMDDYYHHMMSS). The time the image was taken is given as Universal, or Greenwich Mean Time, which is typically 5 hours ahead of Eastern Standard Time. You can keep this long filename or, if you prefer, you can rename your image. Make sure you have saved all the information you will need later.

PROCESSING YOUR IMAGES

Many faint celestial objects (such as galaxies and nebulae) have very low contrast. You may have difficulty even seeing these objects when you look at the preview image that appears in the Image Directory. To enhance these images and bring out the fine details, you must use an image-processing program. The FITS-format image, which you can download to your computer, or open directly in JS9-4L, is the original image that comes back from the telescope. It is a “12-bit” image, meaning that each pixel in the image can have any one of 212, or 4096, grey levels. A FITS (Flexible Image Transport System) file is a special high-quality image format that astronomers use.

The MicroObservatory Image processing application – JS9-4L – enables you to:

- enhance the brightness and contrast of your image
- use different color palettes or “colormaps” to colorize the different levels of black, white and gray
- measure the angular width of an object
- measure the brightness of an object in your image
- create a full-color image from three images taken through color filters

To learn to use JS9-4L, follow the instructions in the lightbox tour that pops up when you open the website, or refer to the video and written tutorials available on the Tools & Training Page.

<https://mo-www.cfa.harvard.edu/OWN/training.html>

PROJECTS AND INVESTIGATIONS

Once you become a pro at basic image processing you might want to deepen your experience. Here’s a short list of just some of the projects and investigations you can explore with MicroObservatory images!

- **Make a Moon Calendar**
Take an image of the Moon every night for a month, and track the phases of the moon. Investigate the shadows on the craters, and what percentage of the Moon is lit up.
- **Create color composite images from RGB**
Take three images of an object using the Red, Green, and Blue filters. Combine them using RGB mode in JS9-4L to see how colorful space really is! Use the How to Create a Simple RGB Image Guide to learn how: https://mo-www.cfa.harvard.edu/OWN/pdf/MOBSQuickGuide_RGB.pdf
- **Follow the brightening and dimming of a variable star**
Variable stars brighten and dim at regular intervals. Use the region stats tools to measure the brightness of a star like Delta Cephei, Algol, Mira, or Beta Lyra over time.
- **Observe the moons around Jupiter just like Galileo**
Request images of Jupiter’s moons, and use the blink tool in JS9-4L to track them as they revolve around Jupiter. Watch this video tutorial to learn how to use the blink tool and create an animation: https://www.youtube.com/watch?v=Asg5OIC36N0&feature=youtu.be&list=PL2TJ0Y_PLXCyc9dIJNKsXaubOwxoboFvq
- **Measure Size and Scale**
Estimate the distance to galaxies that you have imaged yourself. Check out this guide to figure out how big the Universe really is: <https://www.cfa.harvard.edu/webscope/activities/pdfs/galaxies.pdf>
- **Detect an Exoplanet**
Join the search for other worlds using one of MicroObservatory’s other portals- DIY Planet Search –gather data and detect an exoplanet for yourself! <https://www.cfa.harvard.edu/smgphp/otherworlds/OE/index.html>

TIPS AND TRICKS

Bookmark the MicroObservatory website

To access the MicroObservatory Observing with NASA Portal, go to this website:

<http://www.microobservatory.org/>

Printing your images

When you print your images, use the landscape format rather than portrait format (i.e., horizontal rather than vertical). Make sure that you print your images at full scale (100%).

Astronomical images usually have black backgrounds that can use up your printer’s toner ink. If this is a problem, a handy solution is to invert your image before printing it. By printing black against a white background, you will save your toner and also bring out finer details in your object. You can invert your image using the “Color” drop-down list in JS9-4L. Simply choose **Invert Colormap**.

ADDITIONAL RESOURCES

Once you become an expert with MicroObservatory, we hope you’ll want to continue to explore the Universe. Check out these additional resources to find your next astronomy adventure!

NASA's Astrophoto Challenges:

<https://mo-www.cfa.harvard.edu/OWN/astrophoto/index.html>

From the Ground Up! Curriculum:

<http://cfa-www.harvard.edu/webscope>

AstroPix (image galleries from many of the leading astronomical observatories):

<https://astropix.ipac.caltech.edu/>

Recoloring the Universe (learn basic coding to create images of astronomical data):

<https://chandra.cfa.harvard.edu/edu/pencilcode/>

Girls STEAM Ahead with NASA- Light & Color Activity Guide:

<https://media.universe-of-learning.org/documents/girlsSTEAM-Light-Color-ActivityGuide.pdf>

Exoplanet Watch (a NASA citizen science project inviting amateurs to observe transiting exoplanets with small telescopes (like MicroObservatory).

<https://exoplanets.nasa.gov/exoplanet-watch/about-exoplanet-watch/>

Las Cumbres Observatory (a robotic telescope network to engage in authentic research experiences): <https://lco.global/>

GLOSSARY

CCD: CCD stands for charge-coupled device. A CCD is a digital detector that collects electrons in its "light buckets" (called pixels) during the length of the exposure to light. The more photons of light falling on a particular "light bucket" or pixel, the more electrons that pixel will contain (and thus the higher the pixel "value" when that bucket's electronic signal gets converted into an image.

Exposure Time: The amount of time that a CCD detector is exposed to incoming light (controlled in the MicroObservatory telescopes by a mechanical shutter that opens and closes). Exposure time is usually measured in seconds.

Field of View: The area of the sky visible through a telescope, or focused onto a telescope's detector. Field of View is usually measured in angular degrees.

FITS: FITS stands for Flexible Image Transport System, and is an image file format widely used by the astronomical community. Its great advantage over more familiar image file formats, is that a FITS file includes a "Header" that contains all kinds of information about the imaging device used to capture the image; the time, date, and location of the telescope used; and the telescope settings for the observation.

JS9-4L: JS9-4L is a browser-based image processing software application. JS9-4L opens FITS files, and can be used for both image processing and analysis. JS9-4L is based on the scientific tool JS9, used by astronomers at the Center for Astrophysics | Harvard & Smithsonian.

Image Processing: A method of using computers to enhance, manipulate, and analyze digital images and to change how those images are displayed on a computer screen.

Pixel: The smallest individual component of a detector, and of an image or picture—the greater the number of pixels per area the greater the resolution. Each pixel in a telescope image has a numerical value that directly depends on the brightness of the target object in the sky, and the exposure time of the image.

Raw Image: An unprocessed image. It may be hard to see the details of many of the dimmer objects in their raw image state.