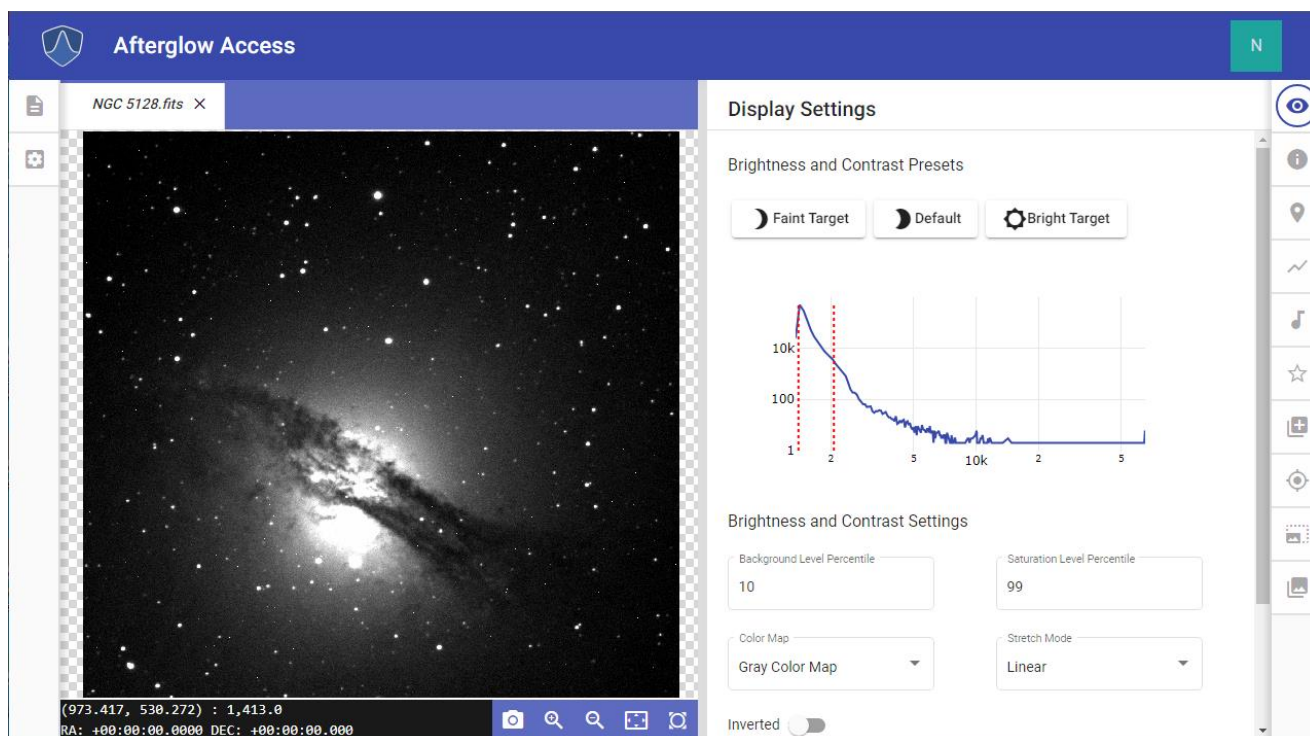


# Afterglow Access (AgA) Software Manual

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## INTRODUCTION

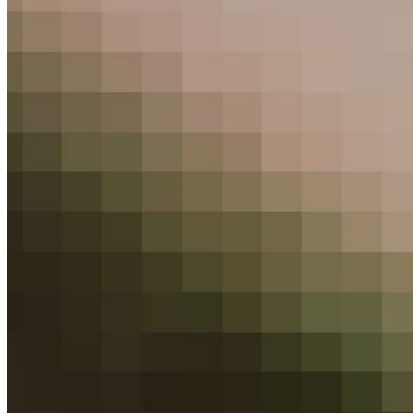
The Afterglow Access (AgA) software was developed by Skynet at University of North Carolina – Chapel Hill as part of the National Science Foundation (NSF) STEM+C project (NSF-1640131) *Research Supporting Multisensory Engagement by BVI and Sighted Students to Advance Integrated Learning of Astronomy and Computer Science* (AKA Innovators Developing Accessible Tools for Astronomy or IDATA).

AgA is a web-based astronomical data analysis software package and was developed in collaboration with blind and visually impaired (BVI) and sighted individuals, including middle and high school students, undergraduate students, astronomers, software engineers, educators, and education researchers. In developing AgA, the group took a different approach and asked, “How can we provide a BVI person with an image analysis experience similar to that of a sighted individual?”

No one looks through a telescope and sees these amazing images of galaxies (see galaxy image below) and other celestial objects. In order to produce an astronomical image, we collect light from distant objects using a telescope, and bring that light to focus on a CCD chip or other detector. These CCD chips are made up of arrays of pixels, and each pixel is a “light detector”.



**Caption:** The image above shows a barred spiral galaxy in the center. The galaxy has a bar-like structure slightly tilted from the upper left to the lower right with a bright central sphere. A spiral arm comes off the right-side of the bar-like structure and wraps across the top of the bar-like structure toward the upper left of the image. Another spiral arm comes off the left side of the bar-like structure and wraps down around the bottom of the bar-like structure to the lower left of the image. The spiral arms are more blue and the bar is more orange in color.



**Caption:** The previous barred spiral galaxy image is composed of an array of pixels. The image above shows a highly zoomed in section of this galaxy image showing a 10 x 10 pixel section (array). The pixels in the upper right are light and they transition to black pixels in the bottom left of the image (data array).

The more light that falls on a pixel, the greater its brightness value. We then use computers to interpret these pixel values and then display the data array visually. In reality, the vast majority of the electromagnetic spectrum is invisible to the human eye. However, we choose to present the data visually, but humans are not limited to just seeing data; we could smell it, taste it, touch it, or hear it.

With AgA a user can choose to explore the data array either with sight (an image) or with sound (sonification). This AgA sonification feature provides users who are BVI the ability to experience an image or the data array through sound.

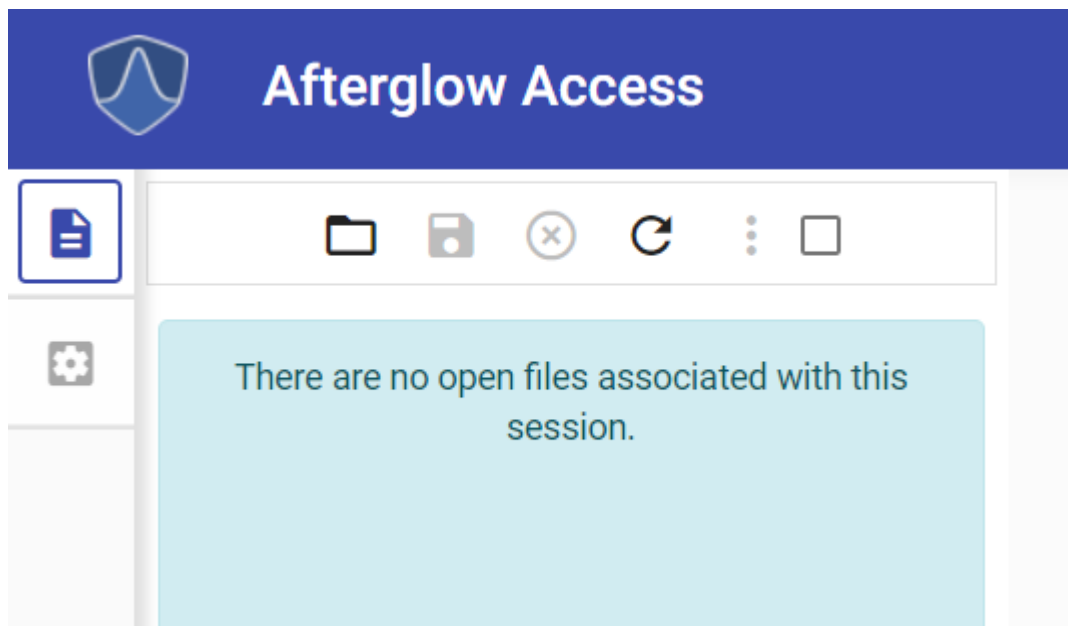
AgA also allows the user to open a variety of file formats, including fits, gif, jpg, etc. Fits files are primarily used in astronomy since the numerical value in each pixel corresponds to brightness. Other image file formats do use pixel arrays, however the value in each pixel may correspond to something other than brightness. As such, we can not accurately measure brightness of objects in image formats other than fits.

**Image Captions:** Please note that image captions in this software manual are intentionally more descriptive in nature. These more detailed descriptions help users who are BVI to better experience the AgA Software manual.

For comments or questions about the AgA Software Manual or accessing AgA, please visit <https://idataproject.org/> and click on the Contact tab to leave a message.

## FILES AND THE FILE LIBRARY LIST

To open a file, navigate to and click on the *File Library List* icon in the upper left-hand corner. Once this icon is selected, there should be five buttons at the top of the File Library List panel. From left to right, they are the **Open Files** button, the **Save All Files** button, the **Close All Files** button, the **Refresh File List** button, and the **Select All Files** button. There is also a list of all open files beneath these buttons.



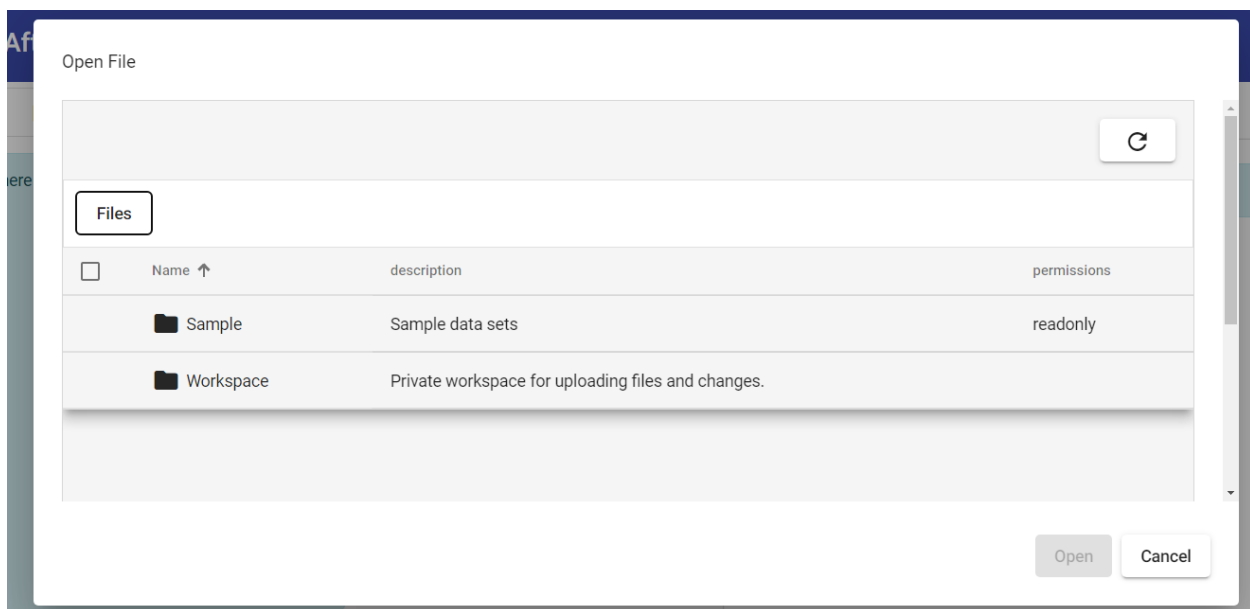
**Caption:** The top portion of the File Library List Panel is shown above. The **Open Files** button, **Save All Files** button, **Close All Files** button, **Refresh File List** button, and the **Select All Files** button is shown at the top of the image. There is also a dialogue box where the file list should be that states, "There are no open files associated with this session."

## Open Files

As the name suggests, the **Open Files** button opens a new file.



When this button is selected, it opens the folder directory. If the user is signed in through Google, there are two different folders present in the folder directory. The first folder is the Sample folder. The Workspace folder is located below the Sample folder.

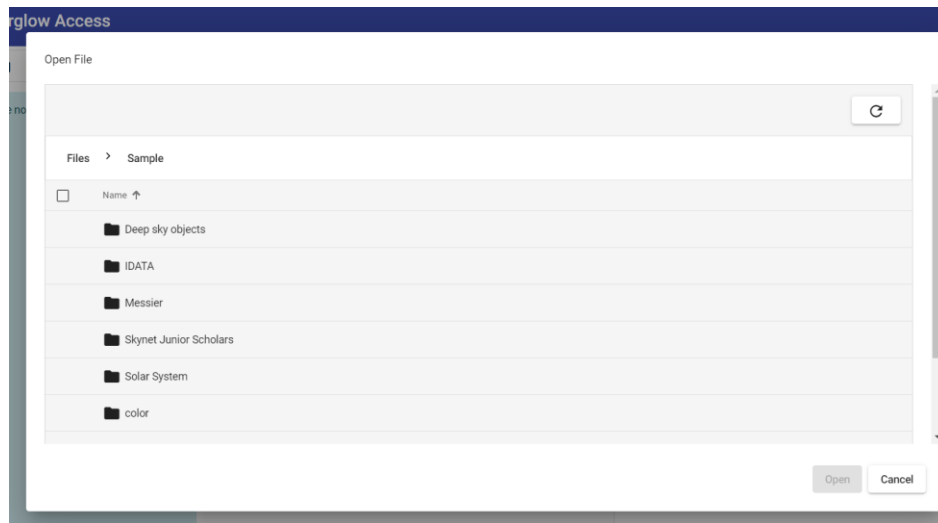


**Caption:** Shown above is the folder directory that is shown when the **Open Files** button is selected. There are two folders in this directory: Sample and Workspace. The Sample folder is listed above the Workspace folder. Additionally, there are two buttons located near the bottom right of the image. The first button is the **Open** button, and directly to the right of this button is the **Cancel** button.

## Sample Folder

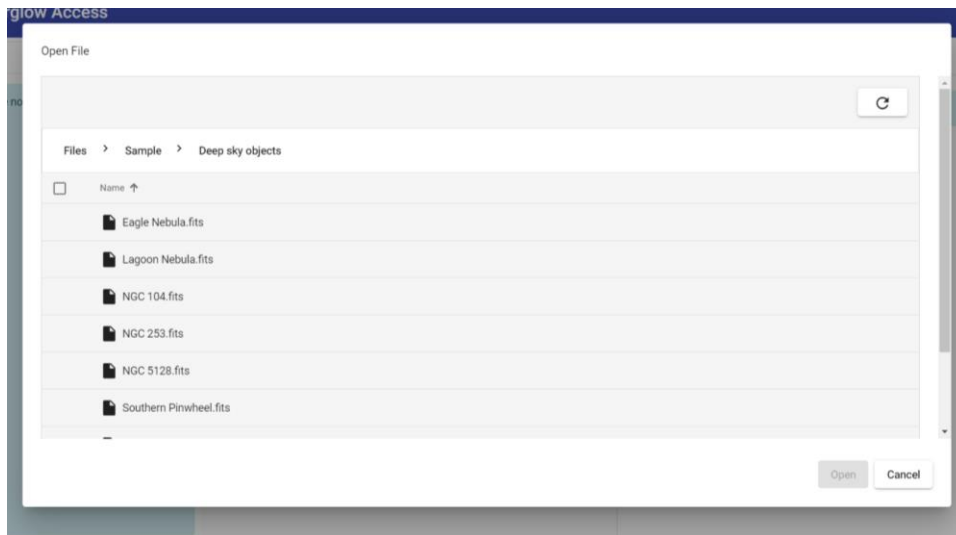
Different sample images are located in the Sample folder. In order to open this folder, either click on the folder and then click on the **Open** button (located near the bottom right of the folder directory) or double click on the folder. There are seven subfolders in the Sample folder. They are Deep Sky Objects, IDATA, Messier, Skynet Junior

Scholars, Solar System, Color, and Sonification. Throughout this manual, the image NGC 5128.fits will be used as a part of the demonstrations. In order to open this file, first open the Sample folder.



**Caption:** The Sample folder directory is shown above.

Next, open the Deep Sky Objects subfolder. It is the first folder listed.

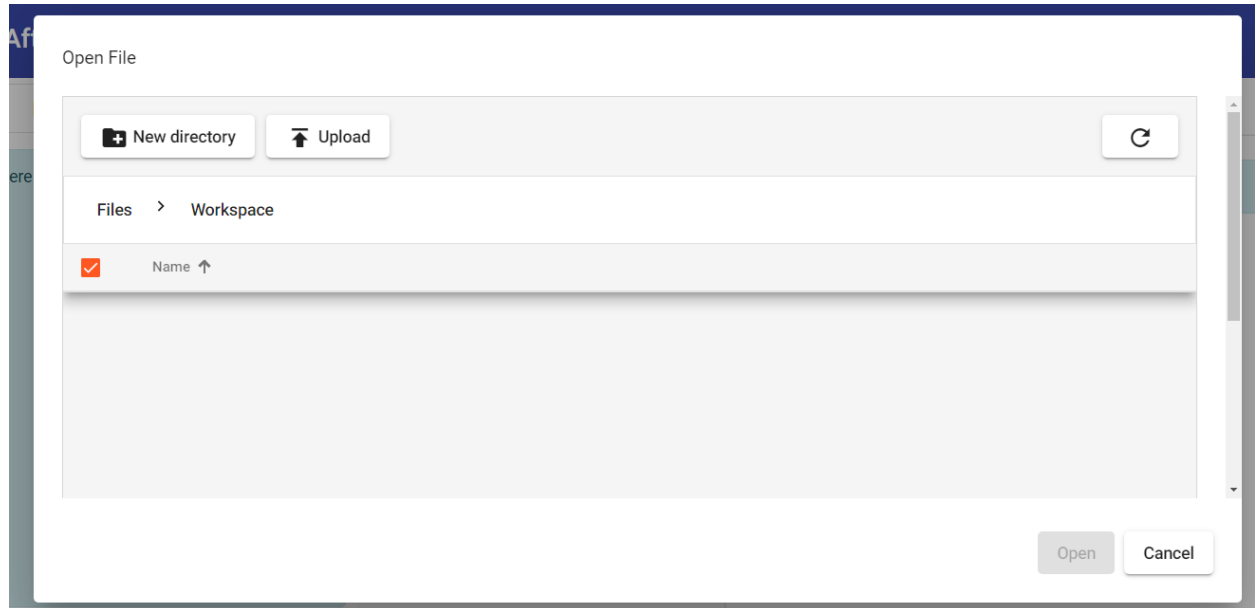


**Caption:** The contents of the Deep Sky Objects folder are shown above.

Finally, double-click on the NGC 5128.fits file. It is the fifth item in the Deep Sky Objects image list.

## Workspace Folder

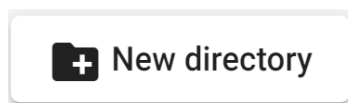
This folder allows the user to import images from their computer. In order to open this folder, either click on the folder and then click on the **Open** button (located near the bottom right of the folder directory) or double click on the folder.



**Caption:** The Workspace folder is shown above with no subfolders. The **New Directory** button and the **Upload** button are located at the top left of the image. Moreover, the **Upload** button is located directly to the right of the **New Directory** button.

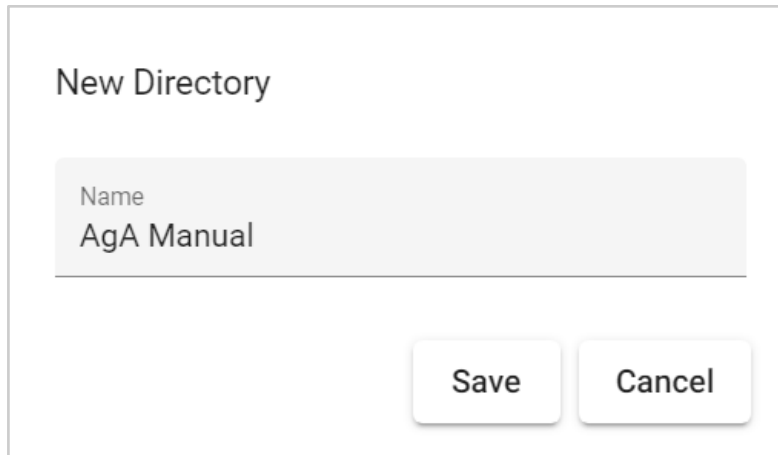
## New Directory

The **New Directory** button creates a new folder directory.

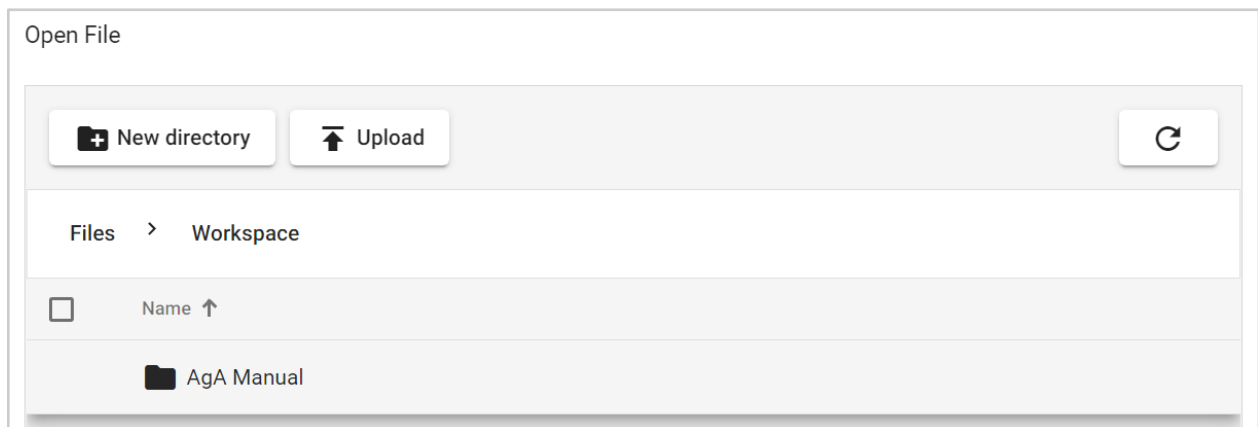


Once this button is selected, a pop-up opens, and the user is able to name the new folder. Once the wanted name is entered, the user can click the **Save** button and the folder will appear.



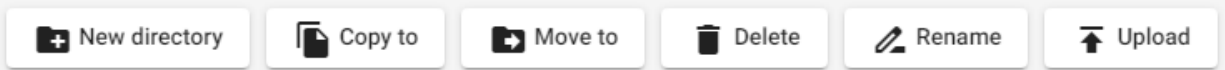


**Caption:** The pop-up window that opens when the **New Directory** button is clicked is shown above. The name “AgA Manual” is already entered into the Name box, which is located in the middle of the image. The **Save** button and the **Cancel** button are located at the bottom right. The **Cancel** button is located to the right of the **Save** button.



**Caption:** The Workspace folder once the “AgA Manual” folder from the previous image was saved is shown above.

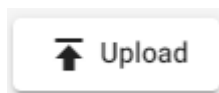
If the user clicks on the **Select All** button, then several buttons appear for the user. They are **Copy To**, **Move To**, **Delete**, and **Rename**. The user is free to explore the related changes that can be made with these buttons.



**Caption:** This is the row of buttons that are visible once the user selects the **Select All** button in the Workspace folder.

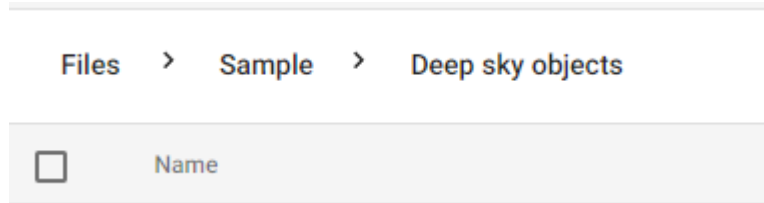
### *Upload*

The **Upload** button allows the user to upload their own pictures and files to Afterglow Access. Once this button is selected, it will allow the user to select and upload pictures from their own computer.



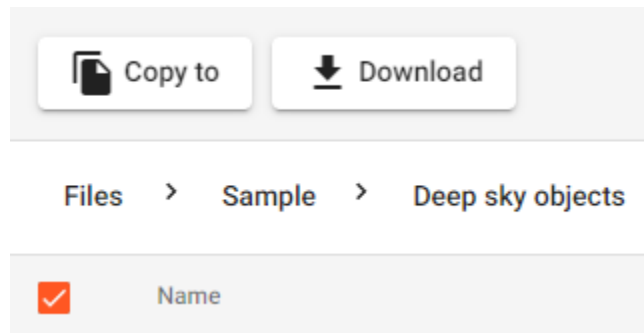
### *Opening a File*

Once the user enters their desired folder and finds the image that they want to open, they can either double-click on the image name or click on the image name and then click the **Open** button, which is located near the bottom right of the folder directory pop-up window. Using the latter method, the user can open multiple images at one time. If the user accidentally clicks on an image, the user simply has to click on an image again to deselect the image. If the user wants to open all of the images in a folder, they can also click on the **Select All** button near the top left of the pop-up window. If it is clicked, there will be a checkmark in the box.



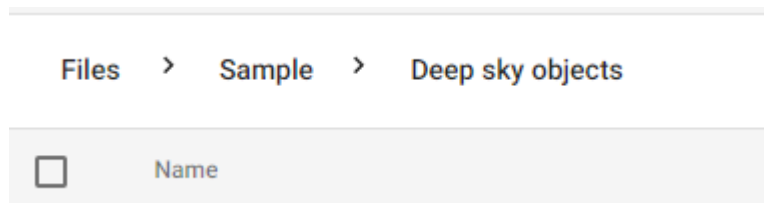
**Caption:** The top portion of the folder directory pop-up window is shown if the Deep Sky Objects folder is open. The **Select All** button is located at the bottom left of the image.

Once it is clicked, in addition to having the option of opening all of the files or folders, the user can also copy all of the files or folders to another folder in the Workspace folder. This can be achieved by clicking the **Copy To** button. The user could also download all of the files to their own computer. This can be achieved by clicking the **Download** button.



**Caption:** The top portion of the folder directory pop-up window is shown if the Deep Sky Objects folder is open and the **Select All** button is selected. The **Copy To** button is located at the top left of the image and the **Download** button is located directly to its right.

If the user ever wants to return to the previous folder or the initial file directory page, simply click on the folder name above the list of either folders or images. For example, once the user was in the Deep Sky Objects folder, they could return to the Sample folder by clicking on the word “Sample” located above the list of images.



**Caption:** The top portion of the folder directory pop-up window is shown if the Deep Sky Objects folder is open. The words “Files > Sample > Deep sky objects” are located at the top of the image. These words are where a user would click to return to a previous folder.

If the user wants to change the alphabetical order of the list, they simply have to click on the **Name** button, which is located to the right of the **Select All** button. The default alphabetical order is A to Z. If the **Name** button is pressed, then the alphabetical order will be reversed (Z to A).

If the user wants to leave the folder directory window, the user simply has to click the **Cancel** button, which is located at the bottom right of the folder directory pop-up window.

### **Save All Files**

The **Save All Files** button allows the user to save all of the files open in their file library list to their Workspace folder, or a subfolder in their Workspace folder. Once the user selects this button, a pop-up opens that asks them whether they want to save all of the images. To save all of the images, select the **Save All** button, which is located near the bottom right of the pop-up window. In order to cancel this action, click the **Cancel** button, which is located at the bottom right of the pop-up window. Once the **Save All** button is selected, simply choose the wanted location in the Workspace folder. It is important to note that in order to keep all of the files that they are using, the user does not have to save the files into a folder before logging off of AgA. If the user logs in using the same method, then AgA will automatically have the same files in the user's file library list.



### **Close All Files**

The **Close All Files** button allows the user to close all of the files open in their file library list. Once the user selects this button, a pop-up opens that asks them whether they want to close all of the images. To close all of the images, select the **Close All** button, which is located near the bottom right of the pop-up window. In order to cancel this action, click the **Cancel** button, which is located at the bottom right of the pop-up window.



### **Refresh File List**

The **Refresh File List** button allows the user to refresh their file list. This can be useful if a file is loading, or if the user suspects that not all of their files are being displayed.



## Select All Files

The **Select All Files** button allows the user to select all of the files. Once this button is selected, the user can click on the three dots to the left of the button. The user will then be given three options in a pop-up list. The first is to download the selected files to the user's computer. To perform this action, simply select the **Download Selected Files** button, which is located at the top of the list. The second button on the list is the **Group Selected Files** button. This allows the user to group the images into one composite image. Once this button is selected, the user has various options available to tweak this composite image. Many of the buttons are located to the right of each image name in the file library list. The user is free to explore these settings. If the user wishes to undo this composite image, they simply have to click on the third button in the pop-up list: **Split Selected Files**. As the name suggests, it will ungroup the selected images.



# 3

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## NAVIGATING THE AgA WINDOW

The Afterglow Access (AgA) main window is made of panels that can be shown or hidden. These panels contain all of the tools used by AgA to analyze and experience the images. There are 13 different tabs or icons that can be selected to display the different panel features of AgA.

### Hiding and Unhiding a Feature Panel

Select or click on any icon to show the feature's panel. Select or click on the same icon to hide that panel. The user can also select a different icon on the same side of the screen to switch between feature panels.

### Keyboard Shortcuts

Keyboard shortcuts can be used to quickly navigate to the different tools and features of AgA. They can also be used to aid in the use of a tool. In this manual, the plus sign, "+", is used to signify that two keys need to be pressed, not that the user needs to press the plus sign. While in some cases, the order in which the keys are pressed does not matter, sometimes the order does matter. The keyboard shortcuts will be given in quotation marks, but quotation marks do not need to be pressed. Additionally, brackets are used to give further description regarding what key should be pressed. To view a complete list of shortcuts, visit the first appendix of this manual.

### What Are the Different Panels?

The top left side of the main window has 2 icons. The icon that is currently selected can be expanded by using the shortcut ",", [comma], and the user can exit the expanded view by using the shortcut "ESC" [escape].

### *File Library List*

The first icon is the *File Library List* icon. Select the icon to show/hide the file library list. This icon is the top icon on the left side.



With the file library list open, the user can open a new file using the **Open File** button. The shortcut to use the **Open File** button is “shift + F”.

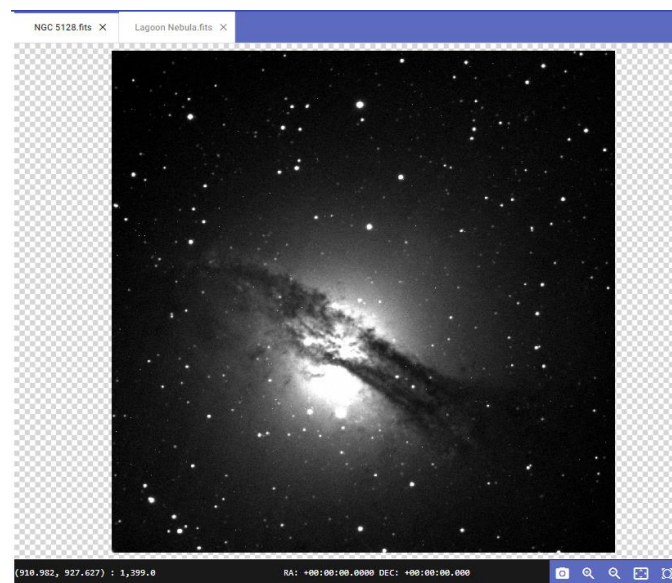
## ***Global Settings***

The second icon, which is positioned below the *File Library List* icon, is the *Global Settings* icon.



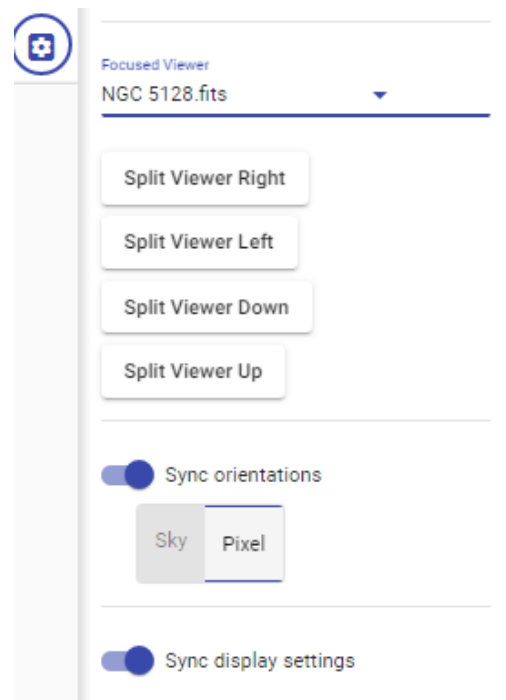
## ***Focused Viewer***

The Focused Viewer feature allows for multiple images to be displayed at the same time. In order to use the Focused Viewer feature, multiple picture tabs need to be opened in the display window. To open multiple pictures, have one picture selected and on display in the display window. Then, double-click on another file in the file library list. Now, above the display window, there should be two tabs. These tabs should be the names of each file.



**Caption:** This image shows the expanded AgA display window. The central portion of the image has an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle.

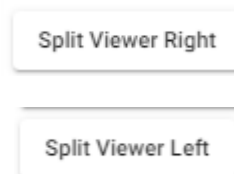
Once multiple files are open, navigate to the *Global Settings* icon. The first option in Global Settings is the “**Focused Viewer**” drop-down menu. The options available in this menu are all of the files that are currently open in the display window. There are four buttons beneath this drop-down menu. These options, from top to bottom, are **Split Viewer Right**, **Split Viewer Left**, **Split Viewer Down**, and **Split Viewer Up**.



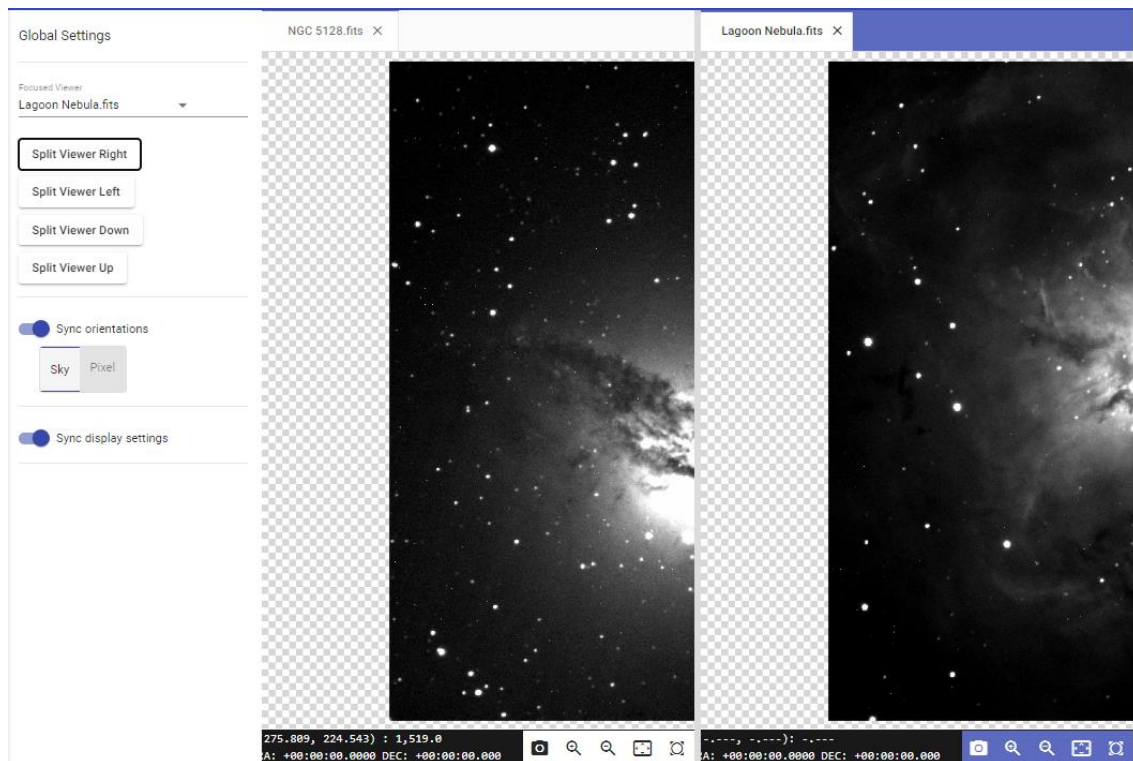
**Caption:** These are the different features of the Focused Viewer feature. They include the **Split Viewer** buttons, the “**Sync Orientation**” toggle button, and the “**Sync Display Settings**” toggle button.

When **Split Viewer Right** is selected, two vertical display windows are created. The image that is selected in the drop-down menu will be displayed in the right window.

When **Split Viewer Left** is selected, two vertical display windows are created. The image that is selected in the drop-down menu will be displayed in the left window.



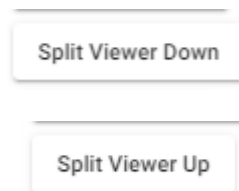


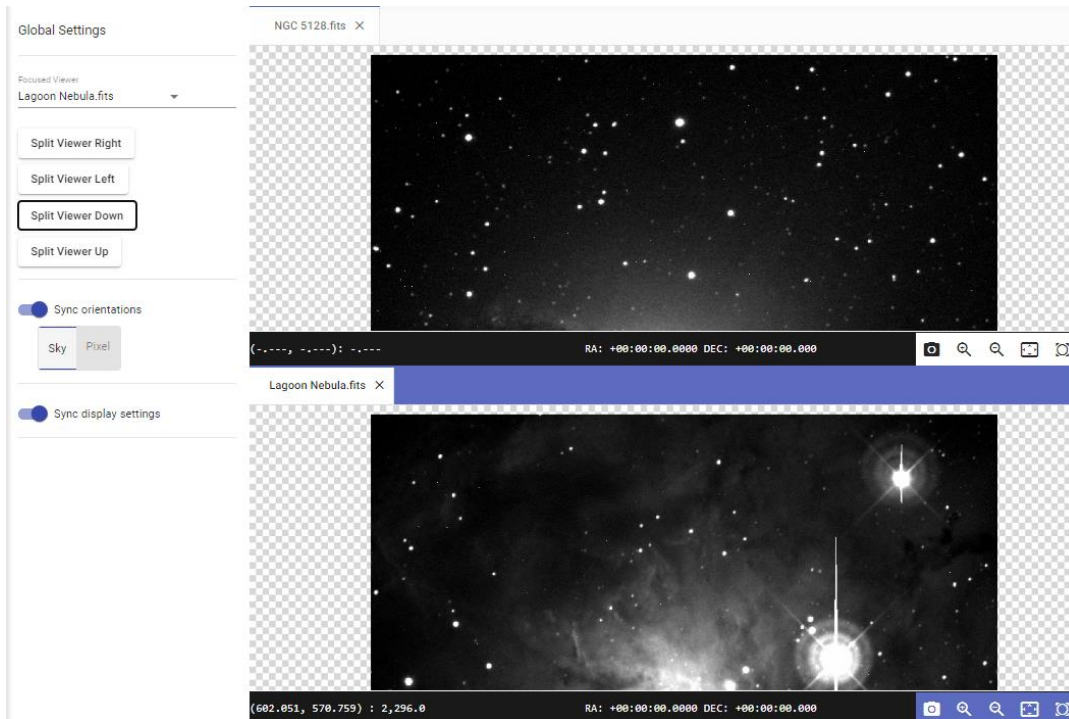


**Caption:** This is the AgA display window when the **Split Viewer Right** button is selected. On the left side of the image is the “**Focused Viewer**” drop-down menu. On the left-hand side of the AgA display window is a partial view of the irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle, but only half of the sphere is visible. On the right-hand side of the AgA display window is a partial view of the Lagoon nebula.

When **Split Viewer Down** is selected, two horizontal display windows are created. The image that is selected in the drop-down menu will be displayed in the lower window.

When **Split Viewer Up** is selected, two horizontal display windows are created. The image that is selected in the drop-down menu will be displayed in the upper window.



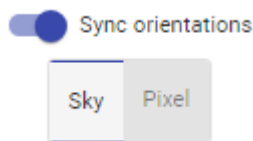


**Caption:** This is the AgA display window when **Split Viewer Down** is selected. On the left side of the image is the “**Focused Viewer**” drop-down menu. On the top half of the AgA display window is a partial view of the irregular galaxy NGC 5128. No discernible features are present. On the bottom half of the AgA display window is a partial view of the Lagoon nebula.

Note: To exit this mode, simply drag the file name tab in the display window to the other display window. This exits the Focused Viewer mode.

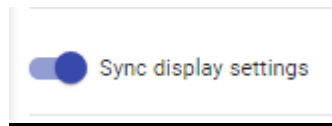
### *Sync Orientation*

The “**Sync Orientation**” toggle button can sync all of the files. If the **Sky** button is selected, then it only matches the right ascension and declination of images in the same area of the sky (as long as they have WCS). If the **Pixel** button is selected, then it matches all of the pixel locations of each file. For example, if the user zooms into one picture, then it automatically zooms into all of the pictures.



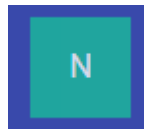
## Sync Display Settings

The “**Sync Display Settings**” toggle button syncs the chosen options in the Display Settings tool panel to all of the files. For example, if the user chooses the **Bright Target** button in the Display Settings tool panel, all of the files would automatically have this preset on them.



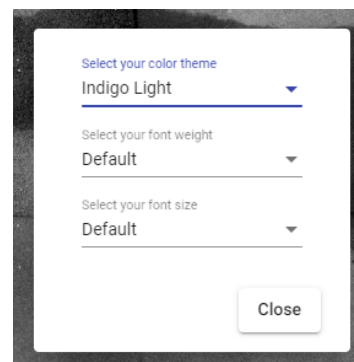
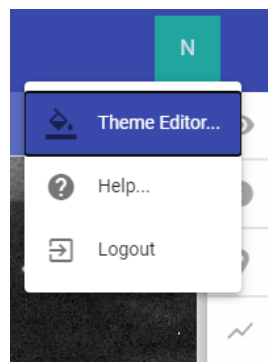
## Account Profile

The *Account Profile* icon is located at the top right of the main window page. This icon has 3 functions.



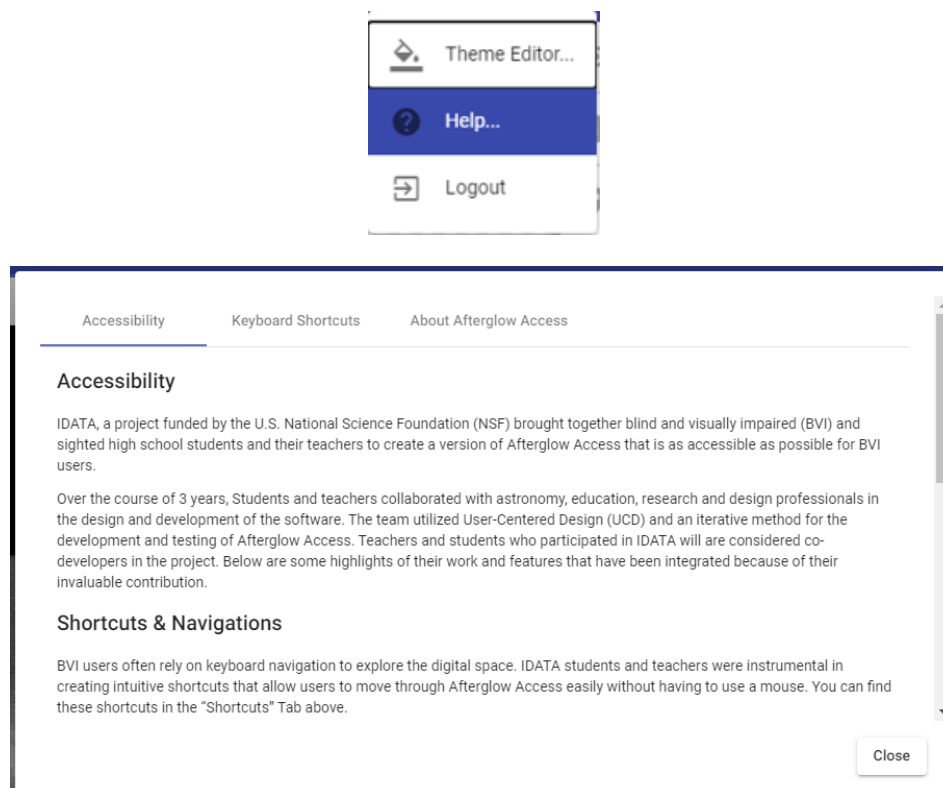
## Theme Editor: Keyboard Shortcut “shift + T”

In the theme editor, the user can select the color theme (the default is indigo light, which is what is shown in all of the pictures in this manual). The user can also select the font weight and the font size.



## Help Tab: Keyboard Shortcut “?”

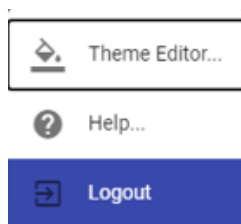
In the Help tab, the user can access information about the accessibility of AgA. The user can also access a list of all of the keyboard shortcuts. Finally, they can read more about the history of AgA.



**Caption:** When a user first opens the Help tab, this is the first tab that is shown. This tab talks about accessibility, shortcuts and navigation, screen readers, themes, and the Sonification tool. It also has the Keyboard Shortcuts tab and the About Afterglow Access tab.

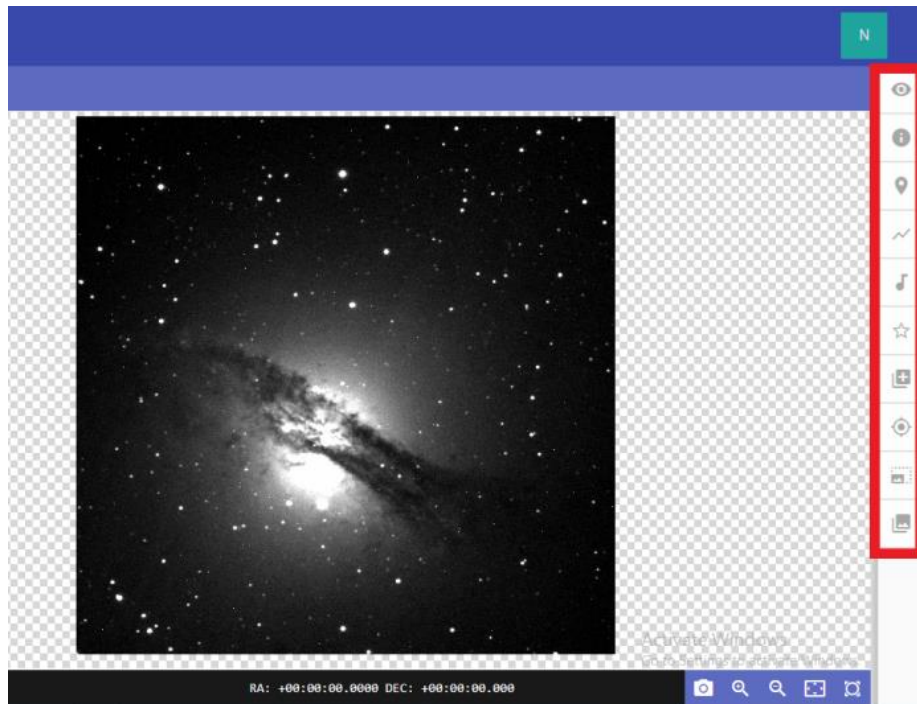
## Logout

To log out of the AgA account, press the **Logout** button, which can be located after the user clicks on the *Account Profile* icon. When the user returns to AgA, all of the files will remain in the file list.



## AgA Features or Tool Panels

The individual tool panels are located on the toolbar on the right-hand side of the main window. The tool panel that is currently selected can be expanded by using the shortcut “/” [forward slash], and the user can exit the expanded view by using the shortcut “ESC” [escape].



**Caption:** The left-hand portion of the image has an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The far-right side of the image has the 10 toolbar icons highlighted in a red box.

Here is a list of all of the icons in the toolbar along with their shortcuts. For more information about each tool, reference the individual sections below.

1. **Display Settings:** The top icon on the right; shortcut “d”



2. **File Info:** The second icon on the right; shortcut “i”



3. **Custom Markers:** The third icon on the right; shortcut “m”



4. **Plotter:** The fourth icon on the right; shortcut “shift + P”



5. **Sonification:** The fifth icon on the right; shortcut “s”



6. **Photometry:** The sixth icon on the right; shortcut “p”



7. **Image Calculator:** The seventh icon on the right; shortcut “\*” [asterisk]



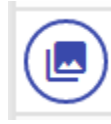
8. **WCS Calibration:** The eighth icon on the right; shortcut “w”



9. **Aligner:** The ninth icon on the right; shortcut “a”

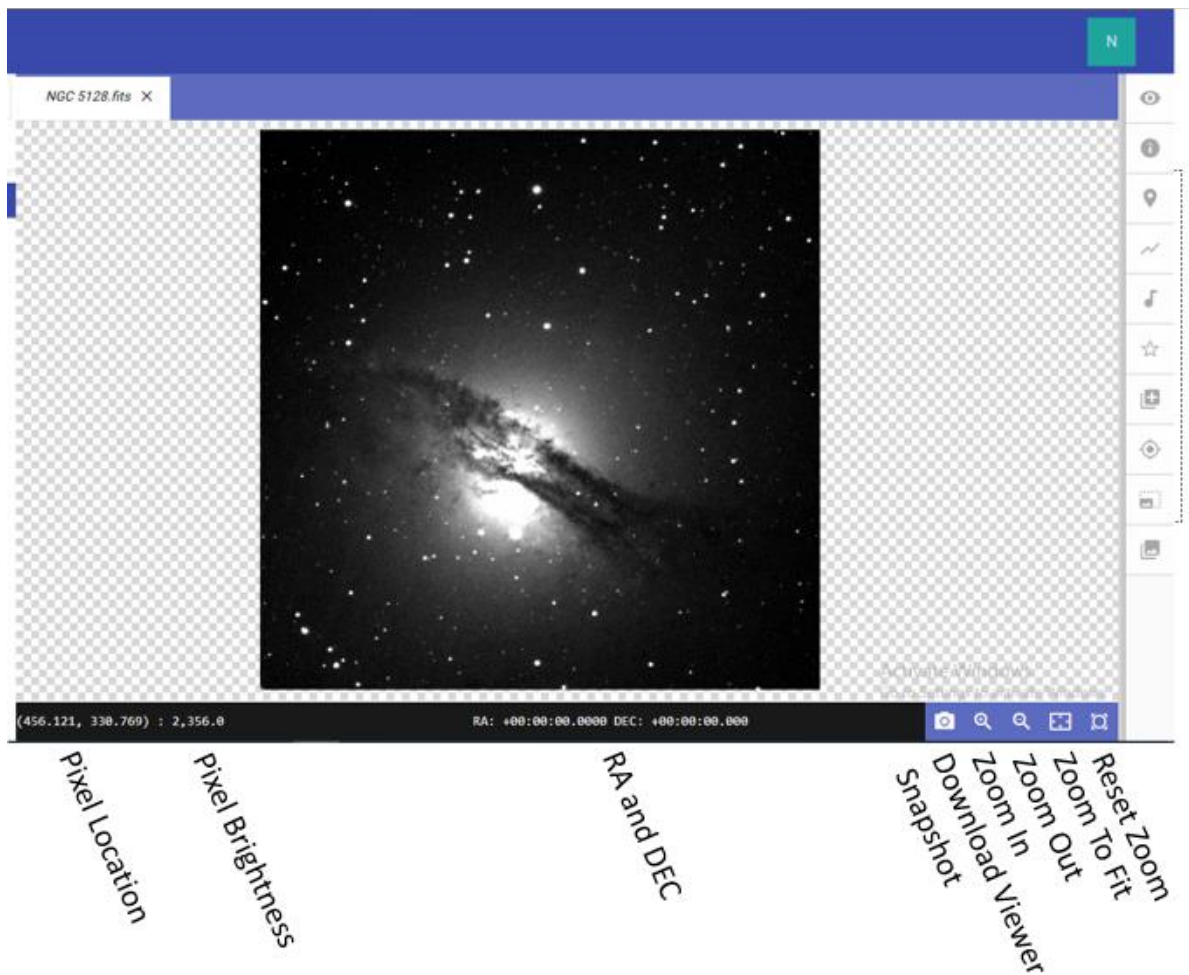


10. **Stacker:** The bottom icon on the right; shortcut “shift + S”



## Image Panel

This panel is accessible once the user has successfully opened an image. It can be expanded using the shortcut “.” [period], and the user can exit the expanded view with the shortcut “ESC” [escape].



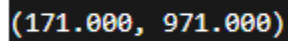
**Caption:** The central portion of the image has an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The bottom of the image has eight icons and values that are displayed on the screen labeled.



The eight icons and values along the bottom of the panel are listed below.

### ***Pixel Location***

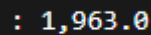
The pixel location of the user's cursor is located on the bottom left of the image. It is in parentheses.



(171.000, 971.000)

### ***Pixel Brightness***

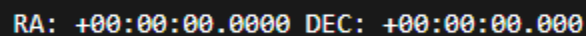
The brightness of the pixel over which the user's cursor is hovering is located on the bottom left of the panel, directly after pixel location.



: 1,963.0

### ***RA and DEC***

The right ascension and declination of the pixel in which the user's cursor is hovering are located on the bottom right of the panel, after the pixel brightness. It is important to note that this is only applicable if the image has been WCS calibrated before being imported to AgA or using the corresponding AgA tool.



RA: +00:00:00.0000 DEC: +00:00:00.000

### ***Download Viewer Snapshot***

The *Download Viewer Snapshot* icon creates a JPEG file that shows the entire main window. It is the first icon after the RA and DEC.



### ***Zoom In and Zoom Out***

The *Zoom In* and *Zoom Out* icons change the view of the entire image by either zooming in (the magnifying glass with the plus sign) or zooming out (the magnifying glass with the minus sign). These icons are located directly to the right of the *Download Viewer Snapshot* icon.





### ***Zoom To Fit***

The *Zoom To Fit* icon automatically adjusts the image to fit in the visible portion of the image workbench panel. It is directly to the right of the *Zoom Out* icon.



### ***Reset Zoom***

The *Reset Zoom* icon resets the zoom to the previous zoom setting before the most recent changes. For example, if the user zooms in to the image, they can return to the view of the image before they zoomed in by using this icon.



## DISPLAY SETTINGS

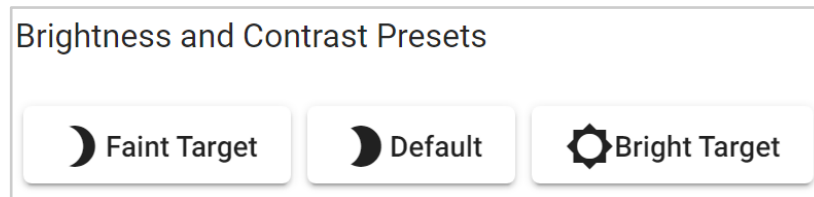
### Keyboard Shortcut “d”

The Display Settings tool allows the user to change how an image is displayed in the image window. In order to access the Display Settings tool, ensure that a file is loaded into the file library list and is displayed in the image display window.



### Brightness and Contrast Presets

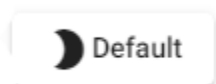
There are three Brightness and Contrast presets. These presets are Faint Target, Default, and Bright Target.

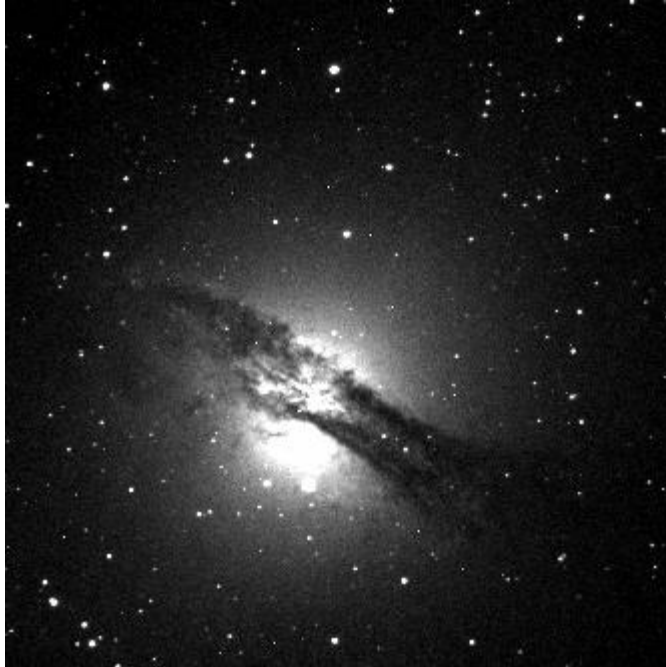


**Caption:** These are the Brightness and Contrast Presets. There are three buttons listed at the bottom of the image. From left to right, they are **Faint Target**, **Default**, and **Bright Target**.

### *Default*

As the name suggests, the default preset is Default. Initially or when this button is clicked, the background level percentile is set at 10%, and the saturation level percentile is set at 99%. The background level percentile is related to what intensity is assigned the color black, and the saturation level percentile is related to what intensity is assigned the color white. A more in-depth discussion of background level percentile and saturation level percentile will be presented below.

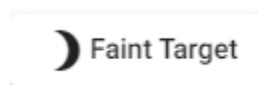


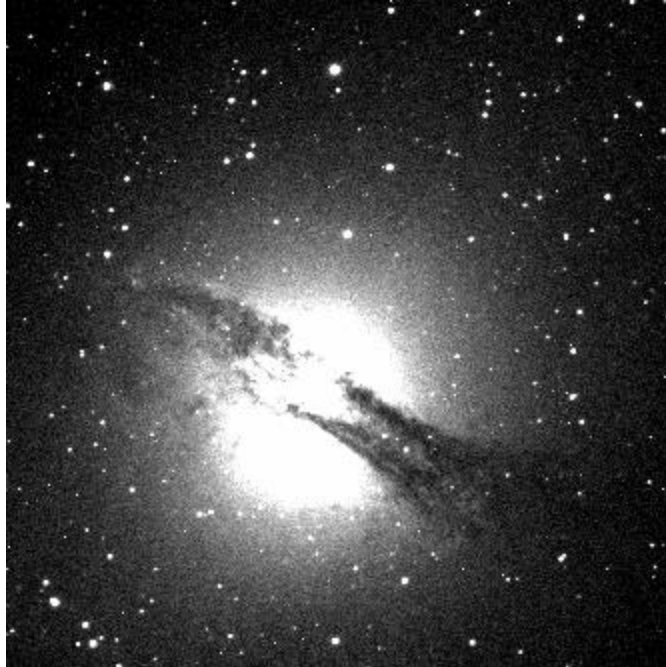


**Caption:** A picture of the irregular galaxy NGC 5128 using the **Default** preset. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle.

### ***Faint Target***

As the name suggests, the Faint Target preset is for faint targets. When the **Faint Target** button is pressed, the background level percentile will be set at 10% and the saturation level percentile will be set at 95%.

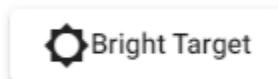


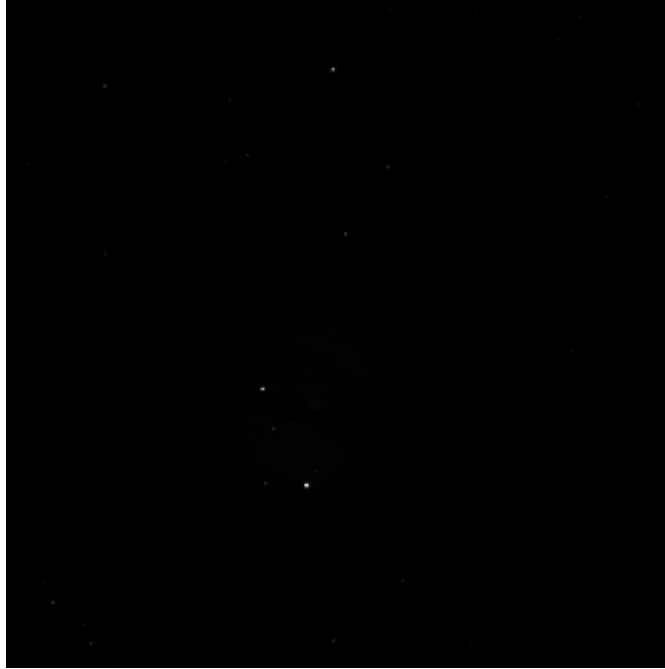


**Caption:** A picture of the irregular galaxy NGC 5128 using the **Faint Target** preset. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle.

### ***Bright Target***

As the name suggests, the Bright Target preset is for bright targets. When the **Bright Target** button is pressed, the background level percentile will be set at 10% and the saturation level percentile will be set at 99.999%.





**Caption:** A picture of the irregular galaxy NGC 5128 using the **Bright Target** preset. Due to this preset, the image only contains several stars.

## **Brightness and Contrast Settings**

These settings allow the user to change the displayed brightness, contrast, and color of the image.

### ***Background Level Percentile, Saturation Level Percentile, and the Histogram***

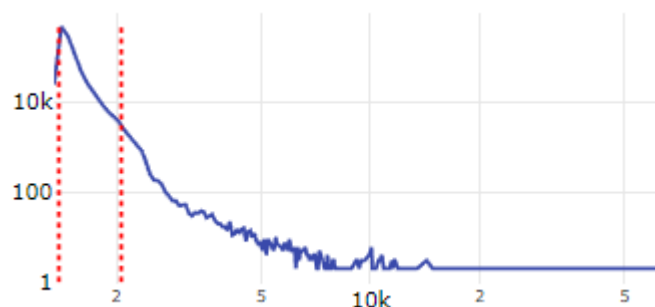
As stated previously, the background level percentile is related to what intensity is assigned to black. Similarly, the saturation level percentile is related to what intensity is assigned to white. The default value for the background level percentile is 10% and the default value for saturation level percentile is 99%. This means that 10% of the pixels in the image have a value below the bottom color in the color scale, and are being shown as that color. Moreover, the brightest 1% of the pixels are being displayed as the top color in the color scale. If a grayscale is being used, then 10% of pixels are being displayed as black and 1% of pixels are being displayed as white. Everything in between these intensity values is being displayed as varying shades of gray.



**Caption:** These are the value boxes for the background level percentile and the saturation level percentile. The value box for the Background Level Percentile is located on the left side of the image, and the value box for the Saturation Level Percentile is located on the right side of the image.

The Background Level Percentile value box allows the user to increase or decrease the background level percentile. The Saturation Level Percentile value box allows the user to increase or decrease the saturation level percentile. This allows the user to fine-tune their images. For example, increasing the background level percentile will limit the dynamic range of the pixels, however, it will also help to increase the preciseness of an image by adjusting the amount of noise that is visible. Fine-tuning the saturation level percentile will also help the user adjust the density of a color. Increasing the saturation level percentile for bright objects will help with properly displaying the image, and may provide the user with a richer color. Similarly, decreasing the saturation level percentile can help display dimmer objects, such as moons. Ultimately, by exploring these settings, the user will be able to customize the images to their own personal aesthetic style.

The histogram that is located above the Background Level Percentile value box and the Saturation Level Percentile value box can be used to help make some decisions about the proper background level percentile value and saturation level percentile value.



**Caption:** A picture of the Display Settings histogram for NGC 5128.fits. The preset used is Default. In the histogram, the x-axis represents the brightness, or intensity, of the pixel and the y-axis represents the number of pixels with that brightness.

In the histogram, the x-axis represents the brightness, or intensity, of the pixel and the y-axis represents the number of pixels with that brightness. The peak of the histogram represents the average brightness of the background of the image. Most pixels in an image are around this value, which is why there is a peak around this value. The pixels to the right of this peak have values above, or are brighter than, the background level. This is where the sources in the image are located.

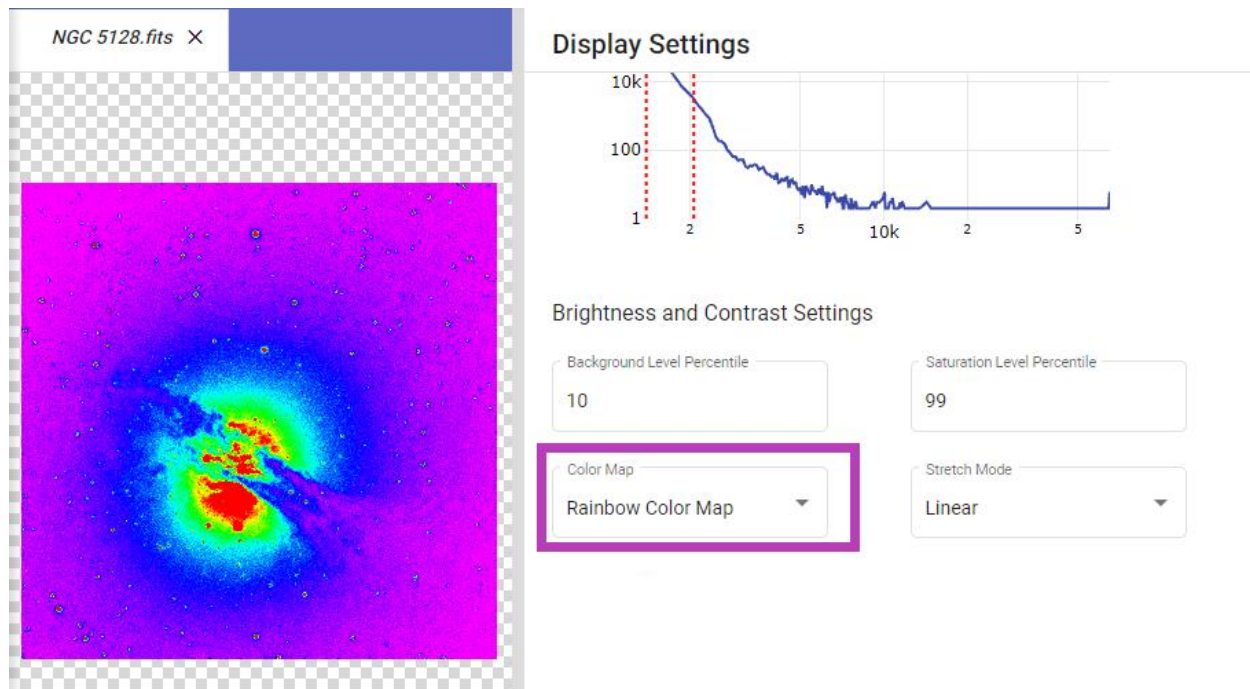
Moreover, in the histogram, the red vertical dashed line on the left line represents the background level percentile. Similarly, the red vertical dashed line on the right represents the saturation level percentile. Therefore, based on the Default preset, the red vertical dashed line on the left is set at the place where 10% of the pixels are to the left of the line. Furthermore, the red vertical dashed line on the right is set at the place where only 1% of the pixels are located to the right of the line. Therefore, in the grayscale, all of the pixels to the left of the red vertical dashed line on the left are assigned the color black. In the same color scale, all of the pixels to the right of the red vertical dashed line on the right are assigned the color white. All of the pixels between these lines are assigned varying shades of gray.

There are several options available to change how the histogram is displayed. When the user hovers over the histogram, several new buttons will appear. These buttons can change whether the x- or y-axis is displayed linearly or logarithmically. They also allow the user to zoom into the graph, zoom out of the graph, or zoom the graph to fit the area.

## ***Color Map***

The “**Color Map**” drop-down menu allows the user to change the color map of the image. Different color maps assign different color schemes to different intensities. More specifically, it changes which color is viewed as the darkest color and which color is viewed as the lightest color. The default for this drop-down menu is the Gray Color Map. This color map assigns black as the darkest color and white as the lightest color. If the colormap is changed to the Blue Color Map, then black is the darkest color and blue is the lightest color. It is important to note that these options are not representative of the true colors of the object, and are not necessarily what the human eye would see.

If the user has images stacked (for more information on stacking, view the stacker section below), they can color map different images. For example, if someone took a picture of NGC 5128 with a blue filter, a red filter, and a green filter, they could color map each respective color to the image and then stack them. This would result in a color composite image. While adjusting the color maps, the user could also adjust other brightness and contrast settings to achieve their desired result.



**Caption:** The left-hand portion of the image has an image of an irregular galaxy NGC 5128 with the Rainbow Color Map. The image has a gas disk stretching from the left middle to the lower right with a colored sphere in the middle. The top right half of the image has a histogram. The x-axis represents the brightness, or intensity of the pixel. The y-axis represents the number of pixels at a specific brightness. The bottom right half of the image showcases the Brightness and Contrast settings. The **“Color Map”** drop-down menu is enclosed within a purple rectangle, for further recognition.

### ***Normalization and Stretch Mode***

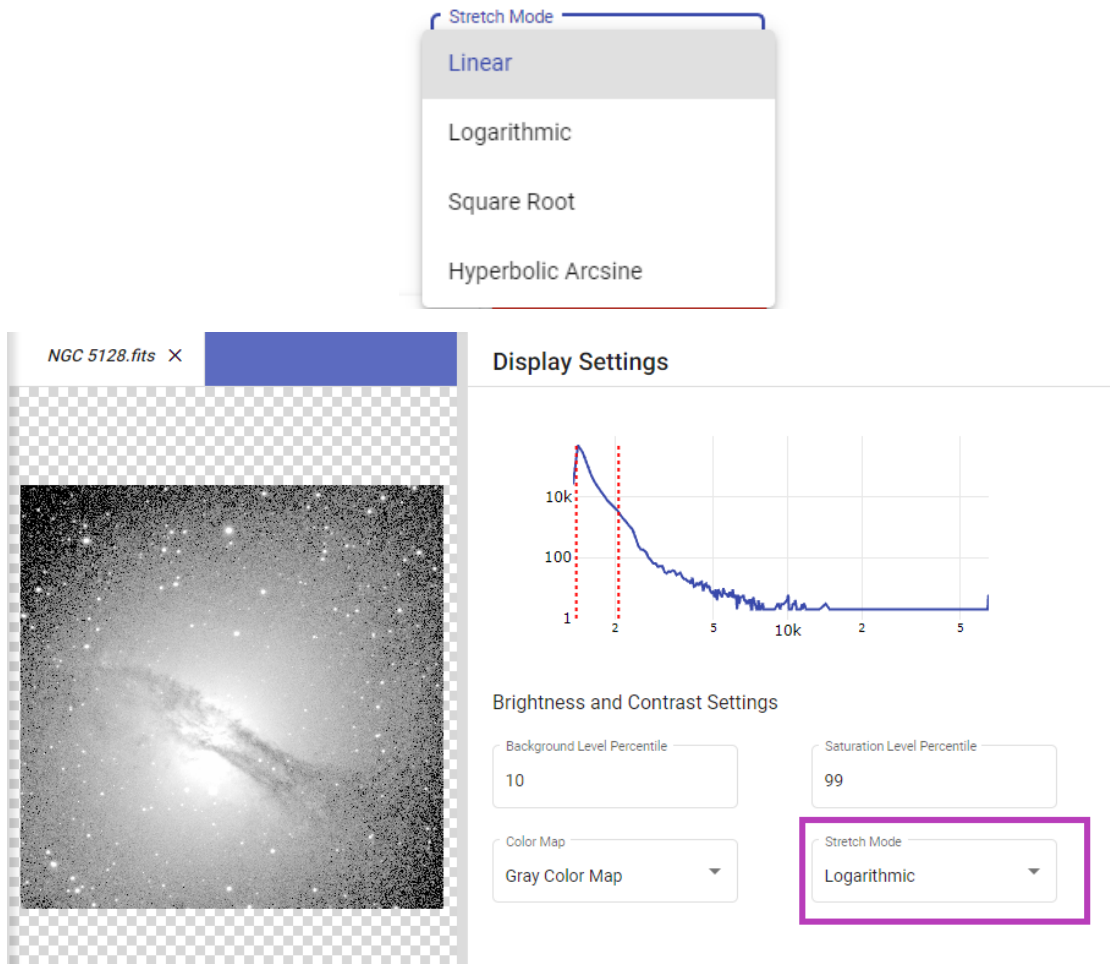
In order for an image to be displayed, every pixel has to be assigned a color. However, there is a finite range of values that can be assigned to a pixel. Each pixel has a red, green, and blue component. The values of each of these have to be between 0 and 255. However, the intensity of the pixels can range from 0 to over 8,000. Therefore, these intensities have to be converted into the correct range. This conversion process is called normalization. The previous subsections of this section have already explained part of the normalization process.

It was explained above that the background level percentile determines which pixels are assigned the darkest color and that the saturation level percentile determines which pixels are assigned the lightest color. Moreover, the color map determines which color



is the darkest color and which color is the lightest color. It follows that stretch mode is the way in which Afterglow Access determines which pixel intensities are assigned the interim colors, or the colors between the two extremes.

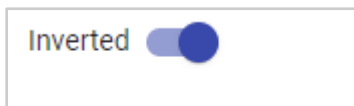
In other words, the “**Stretch Mode**” drop-down menu allows the user to select the way in which the colormap is applied. There are four options in the drop-down menu: Linear, Logarithmic, Square Root, and Hyperbolic Arcsine. The default stretch mode is Linear.



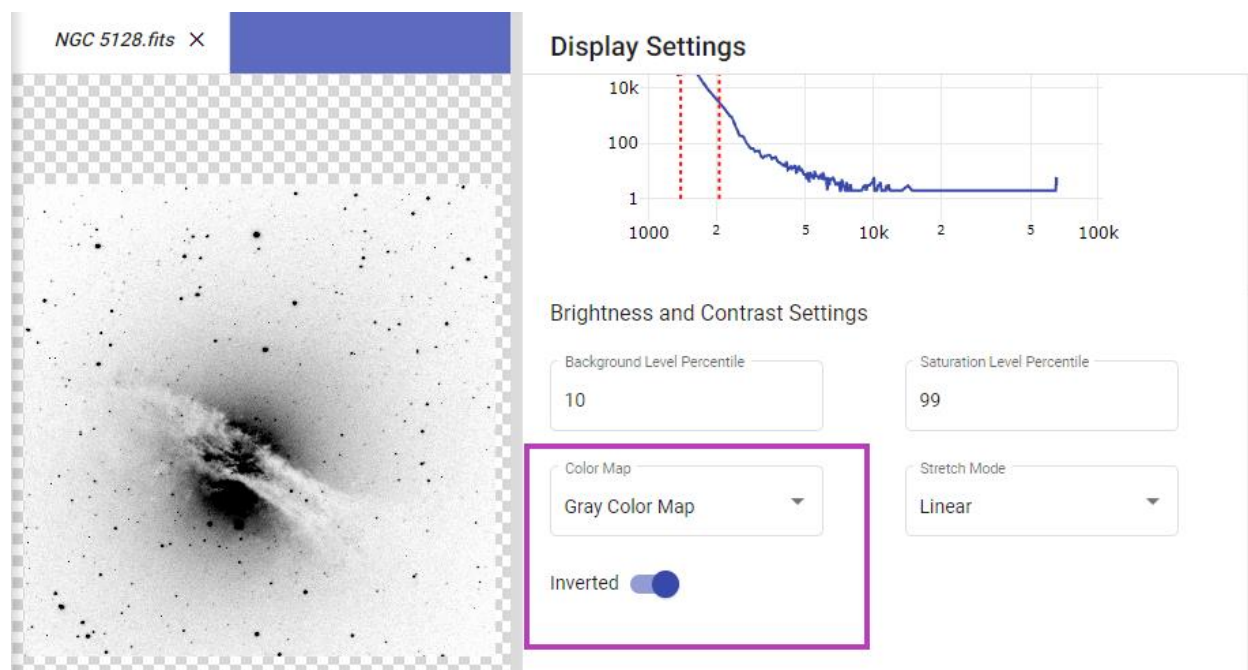
**Caption:** The left-hand portion of the image has an image of an irregular galaxy NGC 5128 with a Logarithmic stretch mode. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The top right half of the image has a histogram. The x-axis represents the brightness, or intensity of the pixel. The y-axis represents the number of pixels at a specific brightness. The bottom right half of the image showcases the Brightness and Contrast settings. The “**Stretch Mode**” drop-down menu is enclosed within a purple rectangle, for further recognition.

## Inverted Toggle Button

If the user selects the “**Inverted**” toggle button, the color map of the image will be inverted.

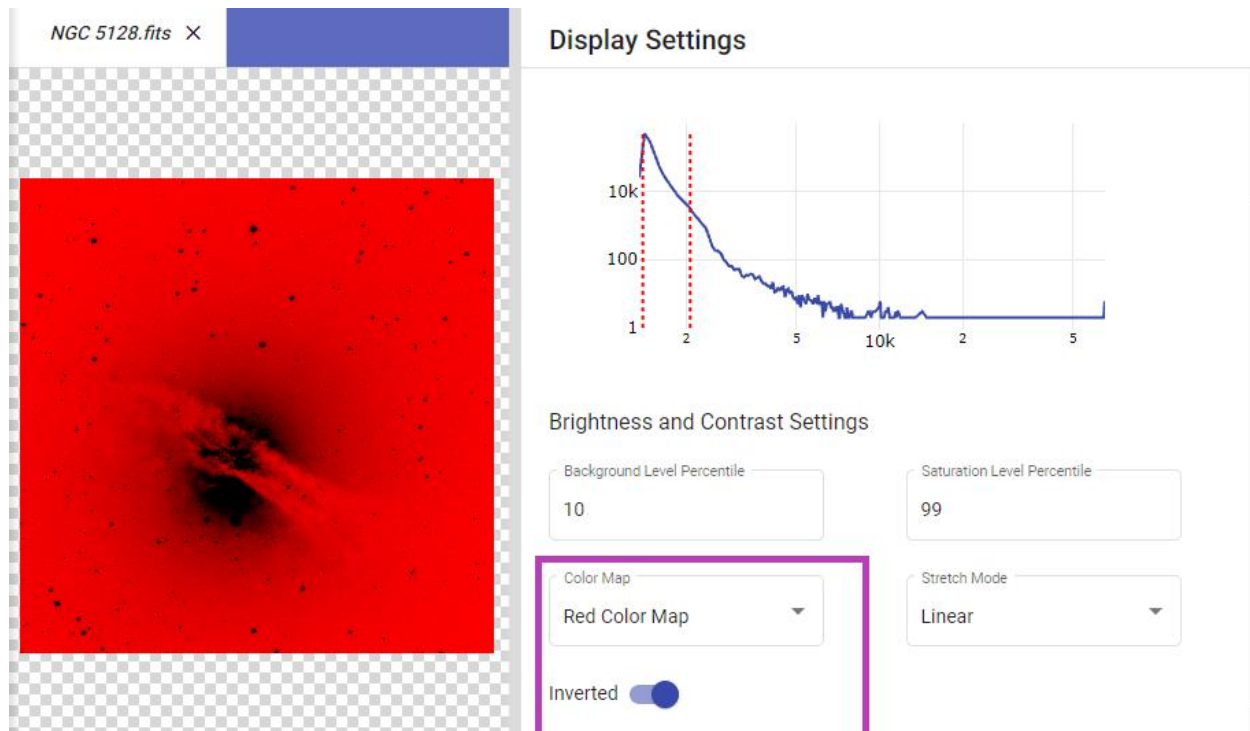


For example, if the user is using the Gray Color Map, before the inversion, black will be assigned to the pixels with the lowest intensity and white will be assigned to the pixels with the greatest intensity. If the “**Inverted**” toggle button is selected, white will now be assigned to the pixels with the lowest intensity and black will be assigned to the pixels with the greatest intensity.



**Caption:** The left-hand portion of the image has an inverted image of an irregular galaxy NGC 5128 with a Gray Color Map. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The top right half of the image has a histogram. The x-axis represents the brightness, or intensity of the pixel. The y-axis represents the number of pixels at a specific brightness. The bottom right half of the image showcases the Brightness and Contrast settings. The “**Color Map**” drop-down menu and the “**Inverted**” toggle button are enclosed within a purple rectangle, for further recognition.

Similarly, if the user is using the Red Color Map, before the inversion, black will be assigned to the pixels with the lowest intensity and red will be assigned to the pixels with the greatest intensity. If the “**Inverted**” toggle button is selected, red will now be assigned to the pixels with the lowest intensity and black will be assigned to the pixels with the greatest intensity.

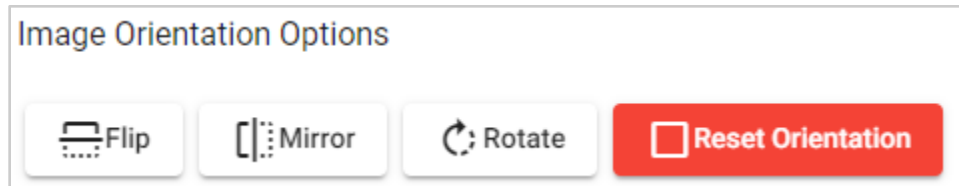


**Caption:** The left-hand portion of the image has an inverted image of an irregular galaxy NGC 5128 with a Red Color Map. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The top right half of the image has a histogram. The x-axis represents the brightness, or intensity of the pixel. The y-axis represents the number of pixels at a specific brightness. The bottom right half of the image showcases the Brightness and Contrast settings. The “**Color Map**” drop-down menu and the “**Inverted**” toggle button are enclosed within a purple rectangle, for further recognition.

## Image Orientation Options

The Image Orientation Options allow the user to change the orientation of the image. There are four buttons in this specific section. From left to right, they are **Flip**, **Mirror**,

**Rotate**, and **Reset Orientation**. The **Flip** button switches the bottom part of the image to the top and the top part of the image to the bottom. The **Mirror** button switches the left part of the image to the right and the right part of the image to the left. The **Rotate** button rotates the image to the right 90°. The **Reset Orientation** button resets the image's orientation to its original position.



Note: An image will only sonify in its original position. See the section on the Sonification tool for more information.

# 5

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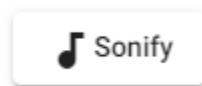
## SONIFICATION

### Keyboard Shortcut “s”

The Sonification tool is an innovative way to translate astronomical images into informative sounds for BVI users.

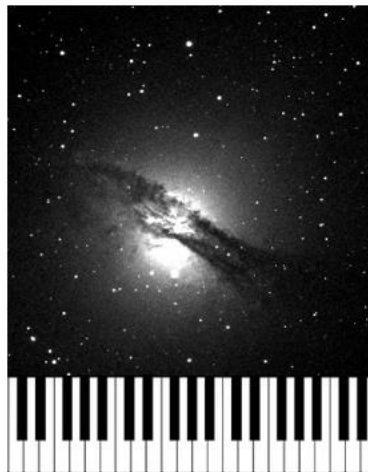


Once an image is uploaded to the viewer, the user may push the **Sonify** button to “hear” the image.



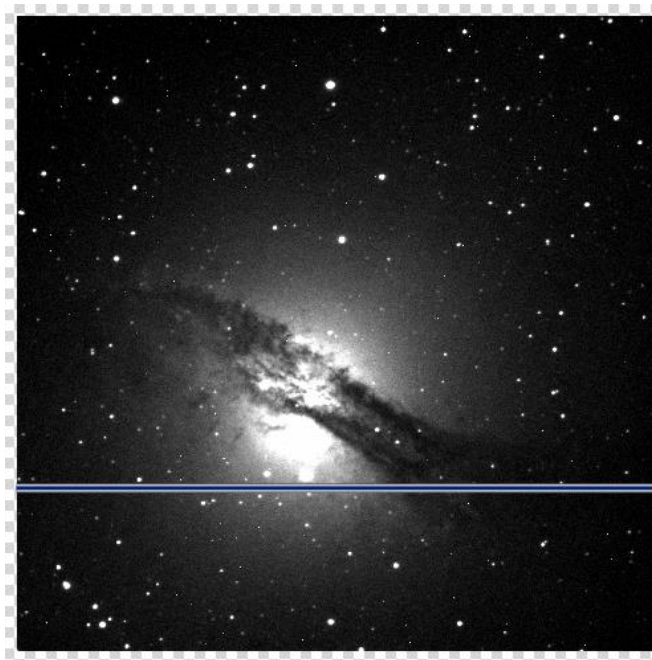
### How it Works

To understand how the sonification tool works, it is best to imagine a piano keyboard stretched across the bottom of the image (as pictured below).



**Caption:** The top two-thirds of this image has an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. Underneath NGC 5128 are 41 piano keys to symbolize how the image is sonified.

When the user clicks the **Sonify** button (the lowest button on the Sonification panel; image available above), this keyboard starts moving up across the image. As this keyboard moves up across the image (shown as a blue line, reference the image below), the pitch determines where the light is located (whether it be a planet, star, asteroid, etc.). If the pitch is lower, it means that it is closer to the left-hand side of the image. Conversely, if the pitch is higher, it means that the object is closer to the right-hand side of the image. There is also a starting and ending tone to signify when the sonification starts and when it ends. When the object is not a point source (like a star), white noise also plays to signify this condition. For example, the user will hear white noise if they sonify a picture of a nebula or even a globular cluster. Additionally, the loudness of a tone signifies how bright the object is. For example, if a tone that signifies a star is louder than a tone that signifies an asteroid, it means that the star is brighter than the asteroid.



**Caption:** This image is an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. There is a horizontal blue line that is located in the bottom third of the image.

Note: Flipping, rotating, and reflecting the image (as described in the Display Settings section) does not change the way in which the object is sonified.

## Duration and Tones

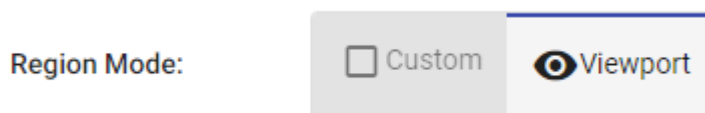
The user can change how the Sonification tool sounds by changing the duration of the sonification and the number of tones used in the sonification.

Duration	Tones
10	22

These tools can be found in the Sonification panel below the “End Pixel” information and above the “**Keep selected region in viewer**” toggle button. The Duration value box is located to the left of the Tones value box. “Duration” determines how long the sonification lasts in seconds. The default duration is 10 seconds. “Tones” determines how many different tones are used in the sonification. For this option, imagine a piano keyboard that has 100 keys versus 10 keys. The default number of tones is 22 tones.

## Region Mode

While flipping, rotating, and reflecting the image does not change the way in which the object is sonified, there are two options (Region Modes) to manipulate the section of the image that is sonified. These options change the amount of the picture that is sonified. The two options are found in either the **Viewport** button or the **Custom** button in the Sonification panel. **Viewport** is the default and that is the top button found on the right, whereas the **Custom** button is at the same height but to the left of the **Viewport** button.



## Viewport

When in the Viewport region mode for the Sonification tool, the amount of picture that is in view determines what is sonified. There are multiple ways to change what amount of the picture is in view. The first option is to zoom with the scroll bar of the mouse. The second option is to use the **Zoom In**, **Zoom Out**, **Zoom To Fit**, and **Reset Zoom** buttons as described in the “Navigating the AgA Window” section.

## Custom

When in the Custom region mode for the Sonification tool, the user can change which areas of the picture are sonified based on an x- and y-axis system. The tone range is represented as the x-axis and the time range is represented as the y-axis. There are three sets of navigation buttons for each axis.



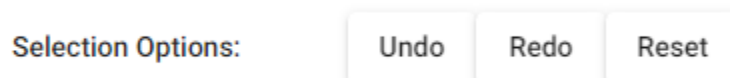
First, right beneath the Region Mode buttons are the Time Navigation buttons. From left to right, they read **Early**, **Mid**, and **Late**. Each of the buttons selects half of the y-axis. The **Early** button selects the bottom half, the **Mid** button selects the middle half (a quarter of the y-axis below and a quarter of the y-axis above), and the **Late** button selects the upper half.



Beneath these buttons are the Tone Navigation buttons. From left to right, they read **Low**, **Mid**, and **High**. Each of these buttons selects half of the x-axis. The **Low** button selects the left half, the **Mid** button selects the middle half (a quarter of the x-axis to the left and a quarter of the x-axis to the right), and the **High** button selects the right half.

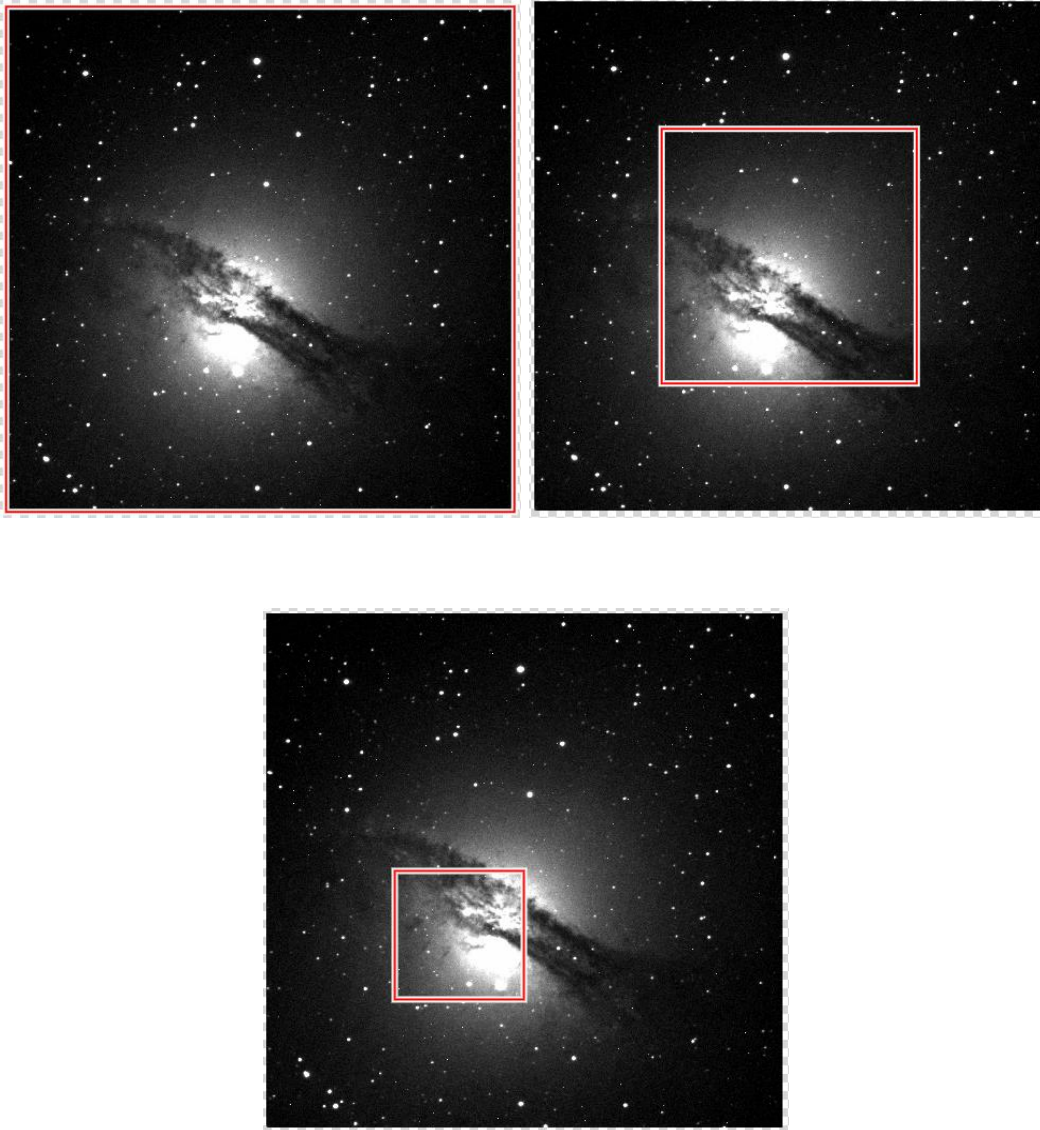


Beneath the Tone Navigation buttons are the Selection Option buttons. From left to right, they read **Undo**, **Redo**, and **Reset**. The **Undo** button undoes the previous selection that the user made. The **Redo** button redoes the selection that the user just undid. The **Reset** button undoes all of the user's selections and makes the entire image the sonification field again.



The Time Navigation and Tone Navigation buttons can be used multiple times. Once one of the buttons is chosen, the same process can be used to further narrow down the sonification field. For example, imagine that a user has identified something of interest in the middle of the image. The user used both the **Mid** Time Navigation and **Mid** Tone Navigation buttons. However, now the user hears the object of interest in the lower-left part of the image. Now, the user can use the **Low** Tone Navigation button and the **Early** Time Navigation button to further confine the sonification field.





**Caption:** There are three pictures of an irregular galaxy NGC 5128, the first two are side by side and the third is located below the other two. The image of NGC 5128 has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The top left image of NGC 5128 is the full image of NGC 5128. This image also has a red square outline on the border of the image. The top right image is the full image of NGC 5128, but the red square outline is in the middle of the image. The bottom image is the full image of NGC 5128, but the red square outline is located on the image such that the bright sphere takes up the majority of the space in the red square outline.

Note: There are keyboard shortcuts, found in the Keyboard Shortcuts subsection of the Sonification section, that can be used to navigate the Custom region mode buttons. For example, there are shortcuts that negate the need to use the different Time and Tone Navigation buttons.

Note: The section of the image that is sonified in this region mode is outlined in red.

### *Keep Selected Region in Viewer Toggle Button*

Above the **Sonify** button and below the Duration and Tones value boxes is the “**Keep selected region in viewer**” toggle button. This button appears for both the Custom and Viewport region modes, but only pertains to the Custom region mode. The default for this button is on. When it is on, as the user uses the buttons or the keyboard shortcuts to zoom into specific sections of the image, that section is automatically zoomed to fit. Otherwise, if the “**Keep selected region in viewer**” toggle button is toggled off, the entire image stays in view and the sonification section can be compared to the entire image. The comparison below shows the difference between when it is on and when it is off.



**Caption:** There are two pictures of an irregular galaxy NGC 5128 side by side. The image of NGC 5128 has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The left image of NGC 5128 is zoomed in so that the center sphere and gas disk occupies the majority of the image. This image also has a red square outline on the border of the image. The right image is the full image of NGC 5128, but the red square outline is in the middle of the image. In both images, the red square outline encompasses the same portion of the entire NGC 5128 image.

## Region Size

For both region modes, like Duration and Tones, three values are always showcased. The first, either below Region Mode (for Viewport) or below Selection Options (for Custom), is the Region Size. This value describes the size of the sonification field.

Region Size:	512 x 512 pixels
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Below the Region Size is the Start Pixel. In the entire pixel grid of the image, it is the specific bottom-left pixel that is first sonified. This value is given as a coordinate pair.

Start Pixel:	(0.5, 512.5)
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Below the Start Pixel is the End Pixel. Similar to the Start Pixel, in the entire pixel grid of the image, the End Pixel is the specific top-right pixel that is last sonified. Its value is also given as a coordinate pair.

End Pixel:	(512.5, 1,024.5)
------------	------------------

For example, imagine that a user has a 1024-pixel by 1024-pixel image. If the user hears something in the upper-left corner of the image and navigates to that section using the **Low** Tone Navigation button and **Late** Time Navigation button, the Region Size would be 512 x 512 pixels. The Start Pixel would be (0.5, 512.5), and the End Pixel would be (512.5, 1024.5).

## Keyboard Shortcuts

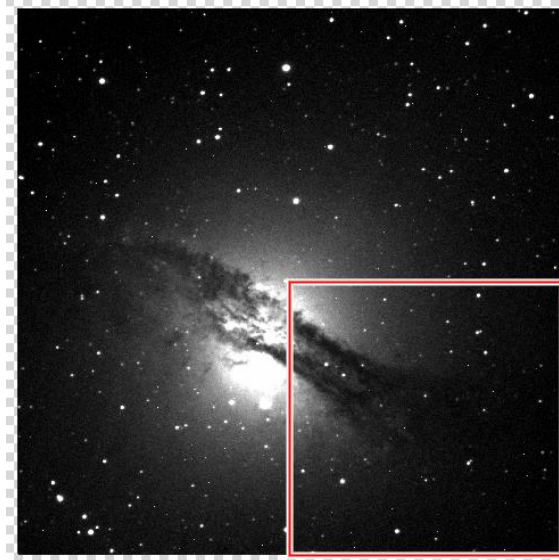
- s – open sonification
- space – play sonification
- ctrl + z – undo region change
- ctrl + y – redo region change
- ← [left arrow] – navigation: low frequency
- → [right arrow] – navigation: high frequency
- ← + → [left arrow + right arrow] – navigation: mid-frequency
- ↓ [down arrow] – navigation: early

- ↑ [up arrow] – navigation: late
- ↓ + ↑ [down arrow + up arrow] – navigation: middle
- 1 – navigation: low frequency | beginning
- 2 – navigation: mid-frequency | beginning
- 3 – navigation: high frequency | beginning
- 4 – navigation: low frequency | middle
- 5 – navigation: mid-frequency | middle
- 6 – navigation: high frequency | middle
- 7 – navigation: low frequency | end
- 8 – navigation: mid-frequency | end
- 9 – navigation: high frequency | end
- 0 – reset sonification region

In the above keyboard shortcuts, when “navigation” is mentioned in the description, it means that the shortcut is related to navigating to different sections of the image. These are also only applicable when the user is in the Custom region mode. Additionally, brackets are used to give further description regarding what key should be pressed.

Note: The plus sign, “+”, is used to signify that two keys need to be pressed, not that the user needs to press the plus sign. While in some cases, the order in which the keys are pressed does not matter, sometimes the order does matter. For example, to navigate to the mid-frequency section of the image, the user needs to press the left arrow and the right arrow at nearly the same time. However, they could press the right arrow slightly before the left arrow, and vice versa. However, to undo the previous region change, they have to click the control key before they click z.

For the keyboard shortcuts 1-9, based on the given parameters, it zooms into the corresponding section. In other words, it makes another square that uses parameters for both axes. This is different from left, right, up, down, left + right, and up + down because these shortcuts only have a parameter for one axis at a time. For example, if the user wanted to hear the beginning part (time-wise) of the image only in the high-frequency range, they would use the shortcut “3” to zoom into this specific section. This would be instead of having to press “right” and then “down.”



**Caption:** This image is an image of an irregular galaxy NGC 5128. There are two pictures of an irregular galaxy NGC 5128 side by side. This image of NGC 5128 has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. On the bottom right quarter of the image, there is a red square outline.

A helpful trick: Imagine that the image is separated into a 3x3 grid, much like a number pad (usually on the right-hand side of a computer keyboard). Each number corresponds to the same section. For example, if the user wanted to select the upper left corner of an image, they would press “7”. It is important to note, however, that using one of these keys still sonifies a quarter of the selected region. Thus, use the number pad or 3x3 grid to only understand the position of the corresponding region, not its size.



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## FILE INFO

### Keyboard Shortcut “i”

The File Info tool allows the user to find basic information about their data files.

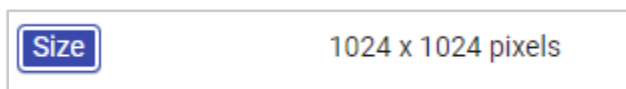


This information is taken from the telescope and can contain information that an astronomer would need to know when working with a dataset.

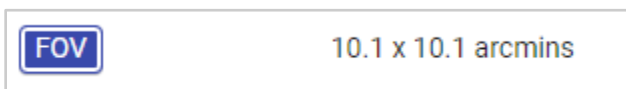
File Info		
<input type="checkbox"/> Show Raw Header Data		
<input type="checkbox"/> Use System Time		
Key	Value	Comment
Size	1024 x 1024 pixels	
FOV	10.1 x 10.1 arcmins	
Start Time	2009-08-21 00:35:44 GMT+0	
Start JD	2455064.524814815 JD	
Center Time	2009-08-21 00:36:04 GMT+0	
Center JD	2455064.5250462964 JD	
Observatory	Prompt4	
Filter	Open	
Exp Length	40	
WCS	false	

**Caption:** These are the different features in the File Info tool. These values are for NGC 5128. They include Size, FOV, Start Time, Start JD, and others. For a full list, read below.

**Size:** This refers to the size of the image or data array. It is measured in pixels.



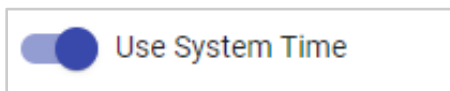
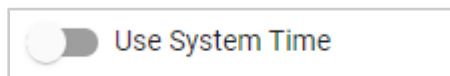
**FOV:** This stands for Field of View. Field of view is the amount of sky visible to the telescope's sensor. The focal length of the telescope and the size of the sensor used to gather the data are the key factors that are related to FOV.



**Start Time:** This is the time when the image's data was starting to be collected. It is measured in the standard time format, and it is listed as year, month, day, hour, minute, second, and time zone. It automatically lists this information in relation to the Greenwich Mean Time or GMT time zone.



If the user selects the “**Use System Time**” toggle button, the time zones shown will adjust to the time zone of the user's current computer system.



**JD Start Time:** This refers to the start time expressed as a Julian date. Mostly used by astronomers, the Julian date is a unit count of 1 per day starting with January 1, 4731 B.C. For example, the date August 20, 2009 at noon Greenwich Mean Time (GMT) would be shown as JD 2455064.0.



**Center Time:** This is the time when the image is halfway through its exposure. It is measured in the standard time format, and it is listed as year, month, day, hour, minute, second, and time zone. As stated previously, it automatically lists this information in relation to the Greenwich Mean Time or GMT time zone.

Center Time	2009-08-21 00:36:04 GMT+0
-------------	---------------------------

**Center Julian Time:** This refers to the time when the image is halfway through its exposure. It is expressed as a Julian date.

Center JD	2455064.5250462964 JD
-----------	-----------------------

**Observatory:** This is the name of the observatory from which the observation was made.

Observatory	Prompt4
-------------	---------

**Telescope:** This is the name of the telescope used to make the observation. In other words, the telescope that took the image. No image of this file information can be given because it was not listed in the file information for NGC 5128.fits.

**Filter:** This shows which filter was used on the telescope, if any, at the time when the data was captured.

Filter	Open
--------	------

**Exposure Length:** This is how long the shutter was open on the camera when the data was captured.

Exp Length	40
------------	----

**WCS:** This refers to whether or not the system has WCS calibration. WCS stands for World Coordinate System. This system maps the pixels in the data to the right ascension and declination coordinates in the night sky. If WCS is listed as true, then the user can figure out the RA and DEC of any pixel in the image/data array.

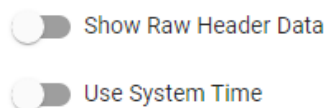
WCS	false
-----	-------



## Show Raw Header Data Toggle Button






There is a **“Show Raw Header Data”** toggle button at the top of the File Info tool panel. The default for this toggle button is off. If this toggle button is toggled on, then other information about the image is displayed. However, this information was deemed by the developers of AgA to not be as vital or commonly accessed. The user is free to explore this information, but for the purposes of this manual, it will not be discussed.

### File Info



#### File Info

☒ Show Raw Header Data

Key	Value	Comment
<b>SIMPLE</b>	true	
<b>BITPIX</b>	-32	
<b>NAXIS</b>	2	
<b>NAXIS1</b>	1024	
<b>NAXIS2</b>	1024	
<b>OBJECT</b>		
<b>TELESCOP</b>		
<b>INSTRUME</b>	Apogee Alta	
<b>OBSERVER</b>	mpsc	

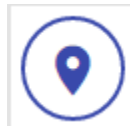
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## CUSTOM MARKERS

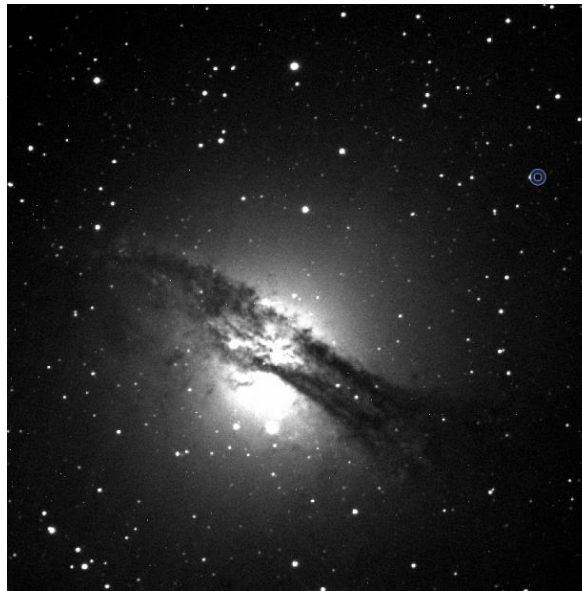
### Keyboard Shortcut “m”

The Custom Markers tool is an AgA tool that allows users to add markers or labels to an image.



### Add a Marker

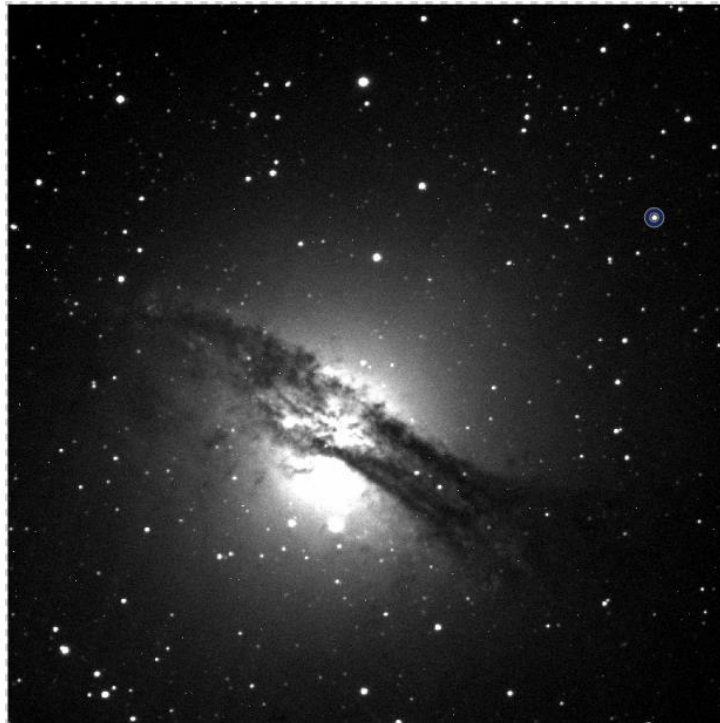
In order to add a marker, the user simply clicks on the spot of the image in which they would like to add a marker.



**Caption:** This is an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a darker sphere in the middle. There is a small, blue circle outline located at the top right of the image. This indicates the marker that was added. It is not centered on a nearby star.

## Centroid Clicks

If the “**Centroid clicks**” toggle button is toggled on, when the user clicks on a star, it will shift the selected starting point towards the point of the peak value.

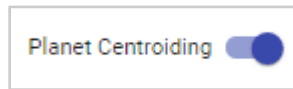


**Caption:** This is an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a darker sphere in the middle. There is a small, blue circle outline located at the top right of the image. This indicates the marker that was added. It is centered on a star.

## Planet Centroiding

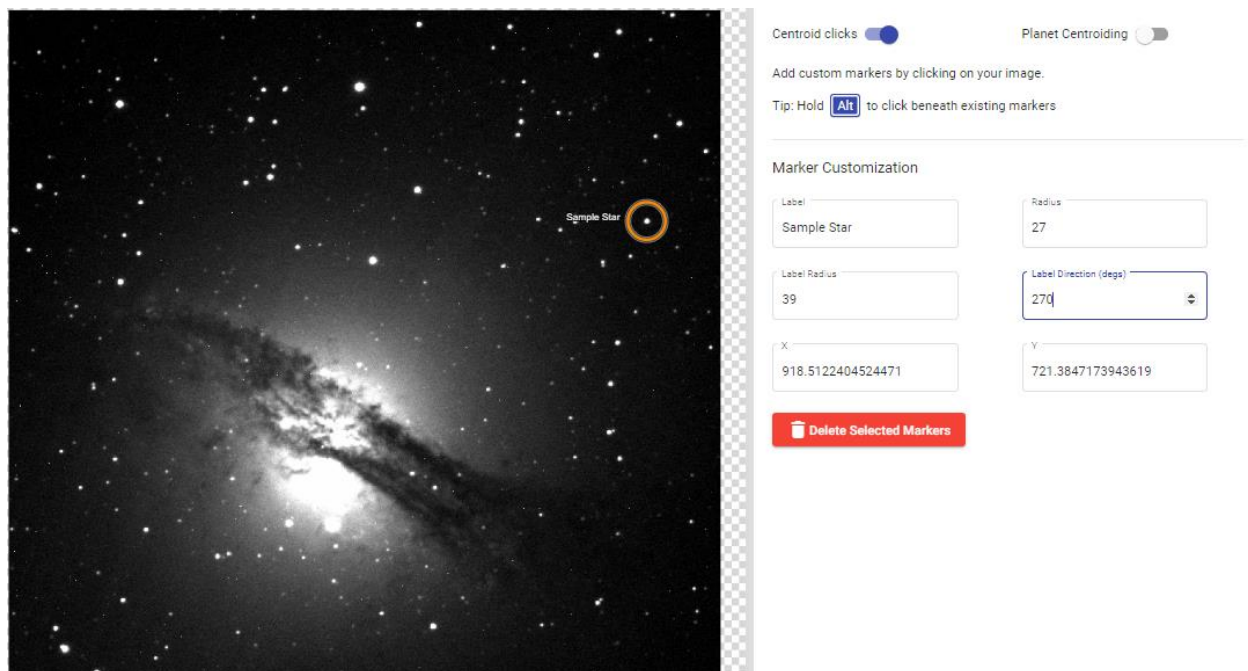
When the “**Centroid Clicks**” toggle button is toggled on, the user also has the option to toggle on the “**Planet Centroiding**” toggle button. If this option is selected, the software will center the starting point on the center of a planet rather than the point of the peak

value. This option uses a slightly different algorithm since planets are disks of light rather than point sources, which makes the first centroiding option not as accurate.



## Marker Customization

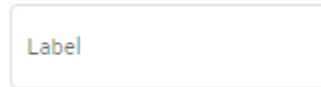
Once a marker has been added, click on the marker to open the Marker Customization settings. The marker will turn orange once it is selected. If the user wishes to place another marker below the existing marker and not open the Marker Customization settings, press and hold the alt button before clicking below the marker.



**Caption:** The left half of this image has an image of an irregular galaxy NGC 5128. NGC 5128 has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The right half of this image shows the Custom Markers tool panel, which indicates the customization options. For more information on all of the features, read below.

## ***Label***

The Label box allows the user to label or name the marker that is selected. For example, in the image above, the marker is labeled *Sample Star*.

A rectangular input box with a light gray border. The word "Label" is written in a small, light blue font at the top left of the box.

## ***Radius***

The Radius value box allows the user to change the radius of the custom marker circle. This is measured in pixels.

A rectangular input box with a light gray border. The word "Radius" is written in a small, light blue font at the top left. The number "10" is entered in a dark blue font.

## ***Label Radius***

The Label Radius value box allows the user to change the radius between the label and the center of the custom marker circle.

A rectangular input box with a light gray border. The words "Label Radius" are written in a small, light blue font at the top left. The number "14" is entered in a dark blue font.

## ***Label Direction (deg)***

The Label Direction value box allows the user to change the position of the label relative to the center of the custom marker. It is measured in degrees and clockwise from the top of the custom marker circle. For example, 0° is located at the top of the circle, 90° is located at the right of the circle, and 180° is located at the bottom of the circle.

A rectangular input box with a light gray border. The words "Label Direction (deg)" are written in a small, light blue font at the top left. The number "0" is entered in a dark blue font.

### ***X and Y (Position)***

The X and Y value boxes allow the user to change the position of the center of the custom marker. The positions are the pixel positions of the image.

X	Y
919	721.5

### ***Delete Selected Markers***

The **Delete Selected Markers** button allows the user to delete the selected marker.



Note: When trying to select a marker, click on the center of the marker not the edge of the marker. Also, the user can put multiple markers on the same image, even in similar locations.

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## PLOTTER

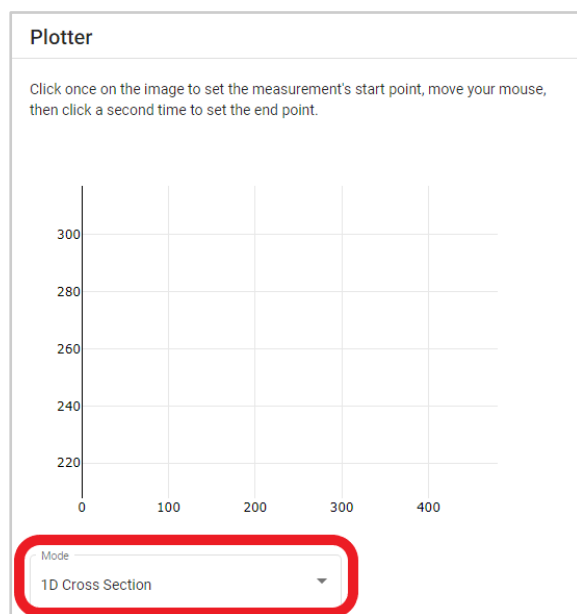
### Keyboard Shortcut “shift + P”

The Plotter tool allows the user to select a cross-section on the image or create a heat map for a selected region of the image.



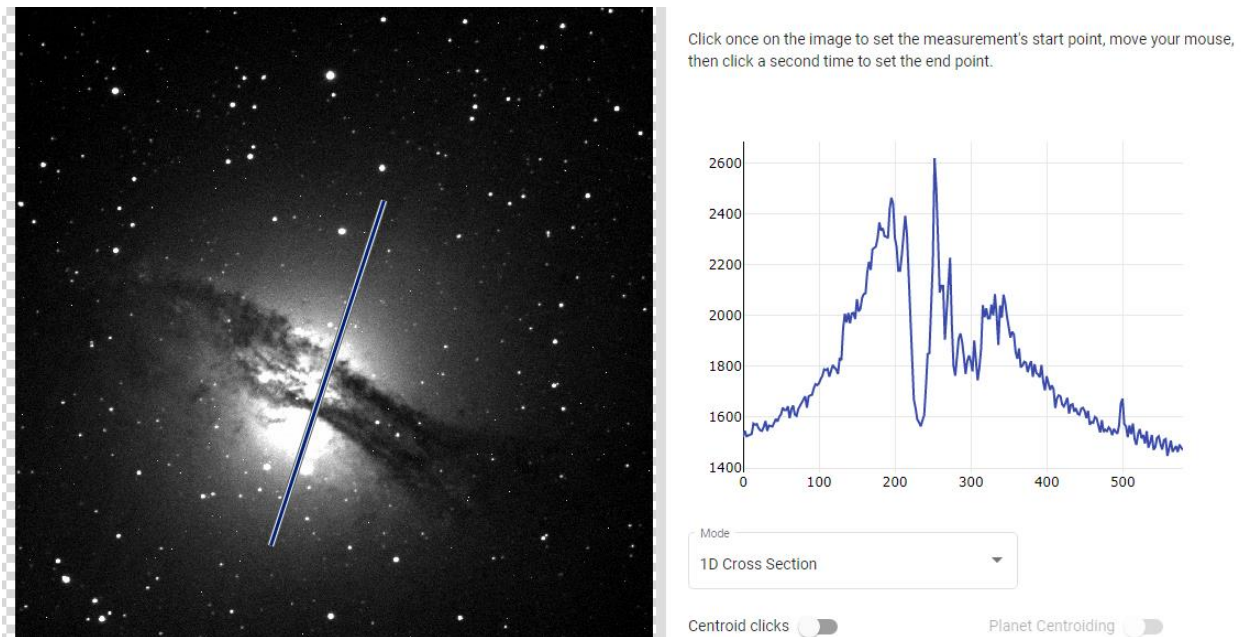
### 1D Cross Section

This feature allows the user to select a cross-section of any region of the image. The cross-section will then graphically display the intensity of light along the selected line.



**Caption:** When the Plotter tool panel is initially opened, this is the 1D Cross-Section graph without any data. It is an x-y plot. The x-axis represents the pixel location along the selected line, and the y-axis represents the brightness (intensity) of the pixel.

To add a cross-section, click on the desired starting point on the image and then click on the desired ending point



**Caption:** The left-hand portion of the image has an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The right half of the image has an x-y plot. The x-axis represents the pixel location along the selected line, and the y-axis represents the brightness (intensity) of the pixel.

The x-axis of the above x-y plot is the pixel location along the selected line and the y-axis is the intensity at the location. In other words, the x-axis represents the position along the selected line.



Mode

1D Cross Section

Centroid clicks

Planet Centroiding

Interpolate pixels

Sync Plot Across Files

Measurement	Value
Start	410.217, 161.279
End	592.066, 713.886
Length	581.759 pixels 343.238 arcsecs 5.7206 arcmins
Orientation	18.215 degrees CW of +Y

**Caption:** When 1D Cross Section is selected in the “**Mode**” drop-down menu, these are the different features and values present in the Plotter tool panel. These values are for NGC 5128. These values are for the selected cross-section. For more information on the features and values, read below.

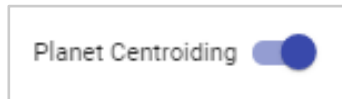
### Centroid Clicks

If the “**Centroid clicks**” toggle button is toggled on, when the user clicks on a star, it will shift the selected starting point towards the point of the peak value.

Centroid clicks

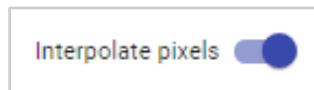
## ***Planet Centroiding***

When the “**Centroid clicks**” toggle button is toggled on, the user also has the option to toggle on the “**Planet Centroiding**” toggle button. If this option is selected, the software will center the starting point on the center of a planet rather than the point of the peak value. This option uses a slightly different algorithm since planets are disks of light rather than point sources, which makes the first centroiding option not as accurate.



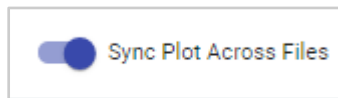
## ***Interpolate Pixels***

If the “**Interpolate Pixels**” toggle button is toggled on, then the graph of the cross-section will be smoothed out. It does not have any effect on the actual points that are selected.



## ***Sync Plot Across Files***

If the “**Sync Plot Across Files**” toggle button is toggled on, then the same cross-section will be automatically placed on a new file.



## ***Measurement***

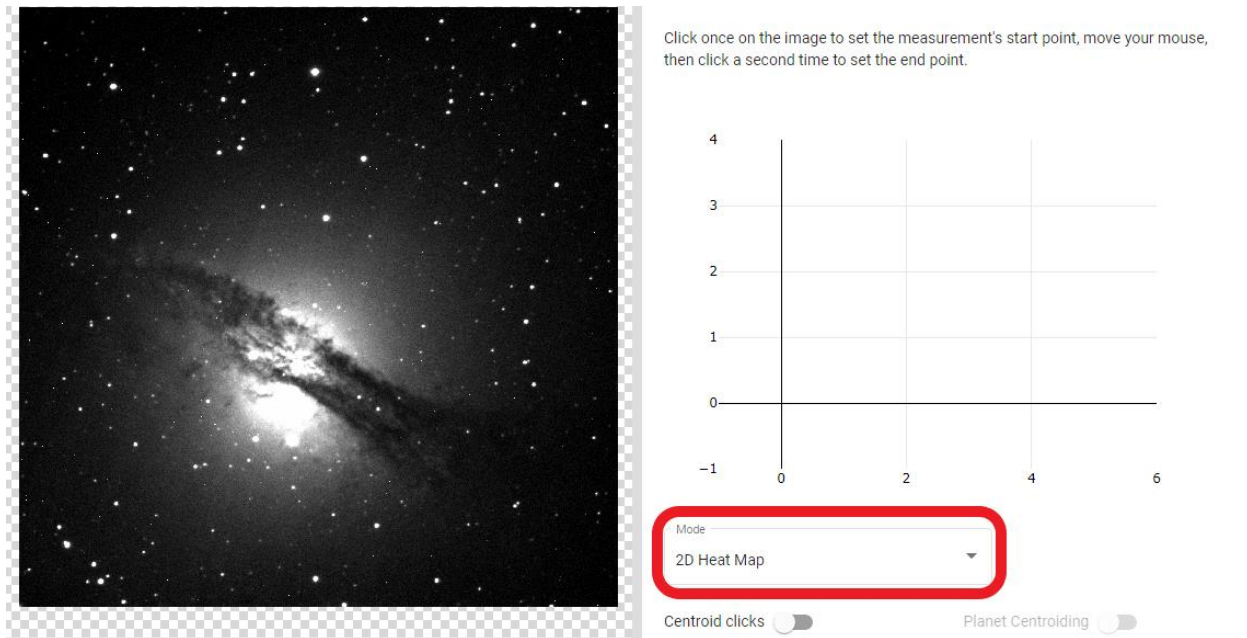
Here are the descriptions of all of the terms listed in the measurement table.

- *Start*: The starting pixel of the cross-section, in relation to the entire image. It is important to note that pixel (0,0) is considered to be the bottom leftmost pixel in the image.
- *End*: The ending pixel of the cross-section, in relation to the entire image.
- *Length*: The distance between the start pixel and the end pixel given in pixels, arcsecs, and arcmins. (Note: Similar to how 60 seconds equals 1 minute, 60 arcseconds equals 1 arcminute.)
- *Orientation*: The degrees clockwise (CW) of the positive y-axis (+Y) or top of the image from the starting point to endpoint. For example, a line that goes straight

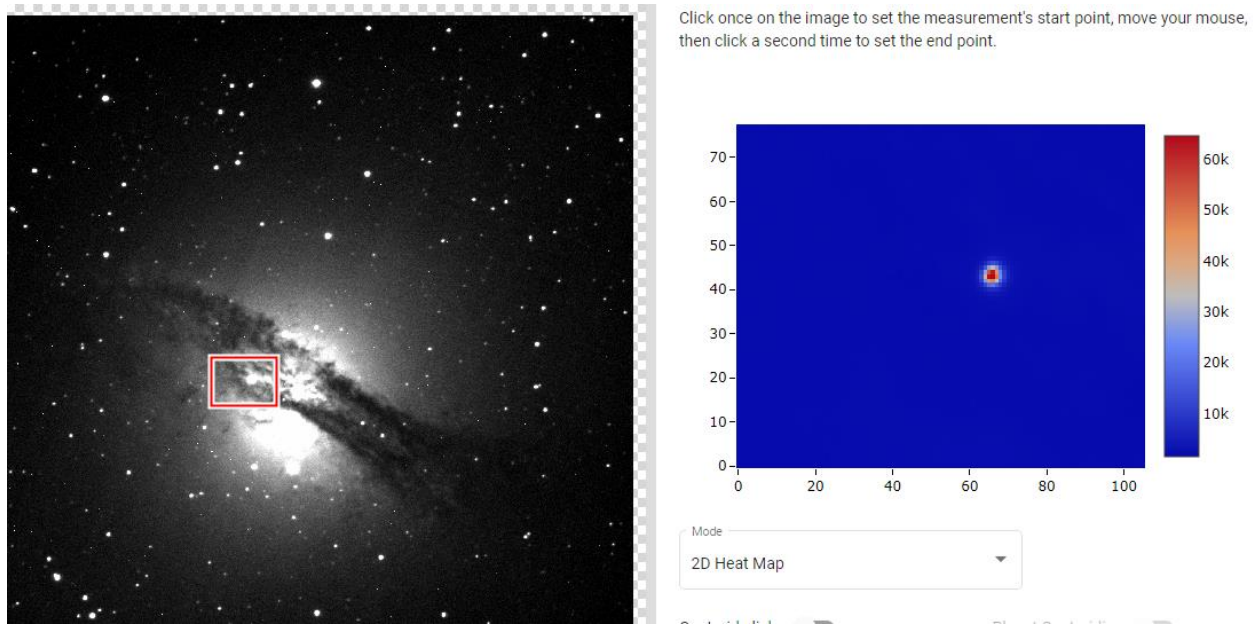
up would have an orientation of 0 degrees CW of +Y, a line that goes horizontal to the right (an arrow would be pointing to the right) would have an orientation of 90 degrees CW of +Y, a line that goes straight down would have an orientation of 180 degrees CW of +Y, and a line that goes horizontal to the left would have an orientation of 270 degrees CW of +Y.

## 2D Heat Map

This feature allows the user to select an area or region of the image. The heat map will then display the intensity of light in the area or region by assigning different colors to different intensities. There is a temperature scale on the right-hand side of the heat map.



**Caption:** The left-hand portion of the image has an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The right half of the image has an x-y plot. The x-axis represents the pixel location along the selected line, and the y-axis represents the brightness (intensity) of the pixel. It also has the “**Mode**” drop-down menu in a red box. The x-axis and y-axis of the heat map are the horizontal and vertical pixel locations in the selected area.



**Caption:** The left-hand portion of the image has an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The right half of the image has a 2D Heat map showing a red spot in a blue background. There is also a bar to the right of the heatmap. It starts at blue on the bottom and then shifts to yellow, orange, and red as the height in the bar increases. This indicates the intensity level.

Mode
2D Heat Map

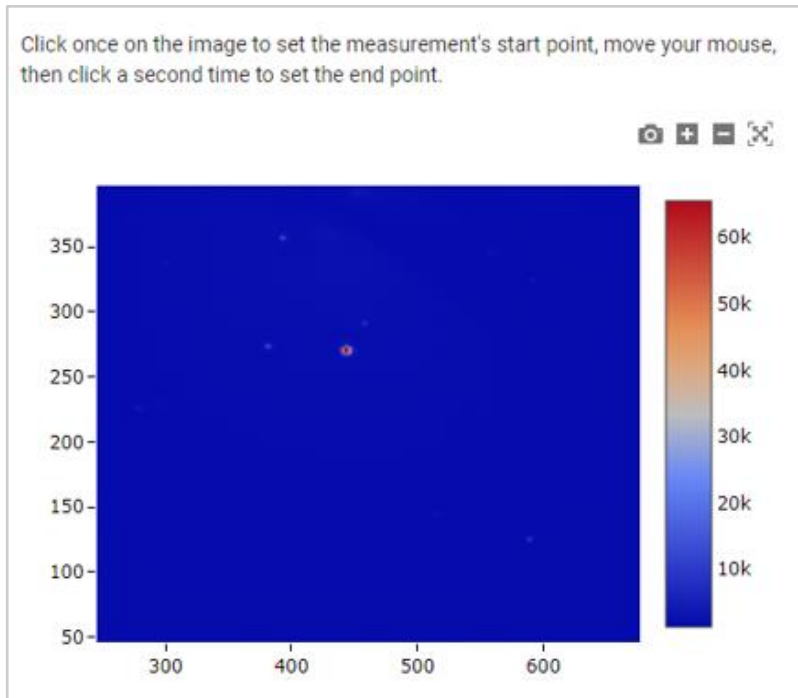
Centroid clicks
Planet Centroiding
Interpolate pixels
Sync Plot Across Files

Measurement	Value
Start	314,384
End	437,463
Length	146.185 pixels 86.249 arcsecs 1.4375 arcmins
Orientation	57.288 degrees CW of +Y

**Caption:** When 2D Heat Map is selected in the “**Mode**” drop-down menu, these are the different features and values present in the Plotter tool panel. These values are for NGC 5128. These values are for the heat map. The different toggle button functions were addressed in the 1D Cross Section section, but for more information on the given values, read below.

**Measurement**

- *Start:* The first pixel that the user clicks.
- *End:* The last pixel that the user clicks.
- *Length:* The distance between the start pixel and the end pixel given in pixels, arcseconds, and arcminutes.
- *Orientation:* The degrees clockwise (CW) of the positive y-axis (+Y), which is determined by the starting pixel to the end pixel.



**Caption:** The image has a 2D Heat Map showing a red spot in a blue background. There is also a bar to the right of the heatmap. It starts at blue on the bottom and then shifts to yellow, orange, and red as the height in the bar increases. This indicates the intensity level.

### ***Zooming Features***

There are four buttons that control the user's view of the heat map. These icons are located to the top right of the heat map.

First, there is the **Download plot as a png** button. This button allows the user to take a screenshot of the heat map.



Second, there is the **Zoom In** button that zooms into the heat map.



Third, there is the **Zoom Out** button that zooms out of the heat map.



Fourth, there is the **Autoscale** button. If this button is selected, the zoom of the heat map will resize to its original size.



Note: Flipping, rotating, and mirroring the object does not change the orientation in which the heatmap is displayed.

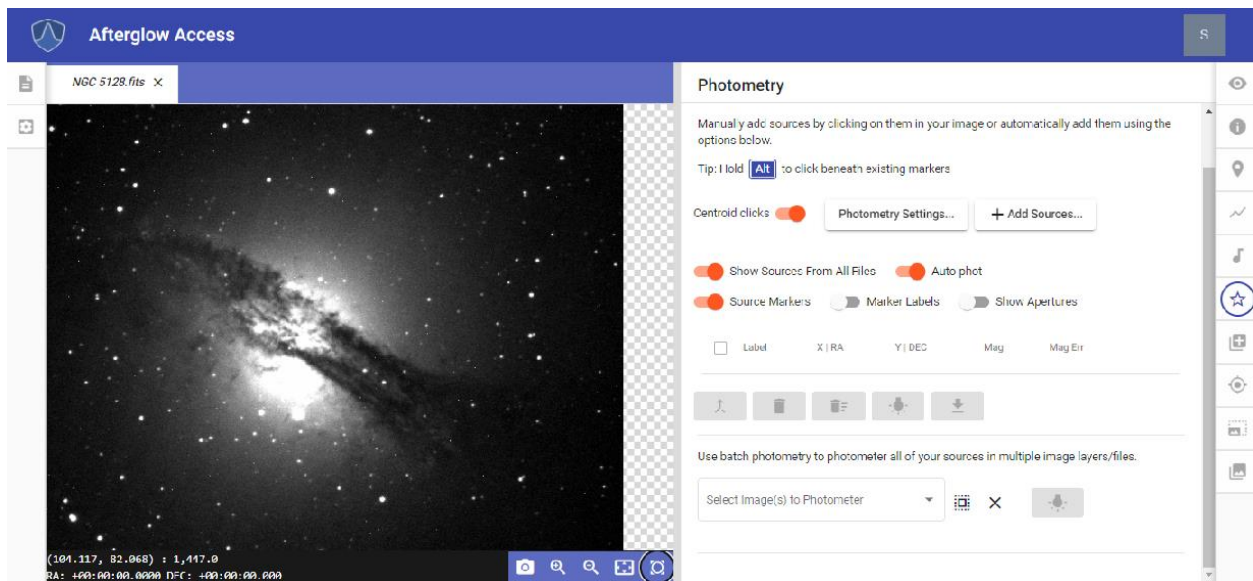
## PHOTOMETRY

### Keyboard Shortcut “p”

The Photometry tool allows the user to determine the apparent magnitude of a light source in an image.



First, the user should open the image they wish to work with. This section utilizes the file NGC 5128.fits and some of the Kleopatra images.



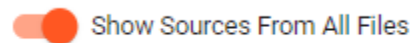
**Caption:** The left-hand portion of the image has an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The right half of the image has the upper portion of the Photometry tool panel.



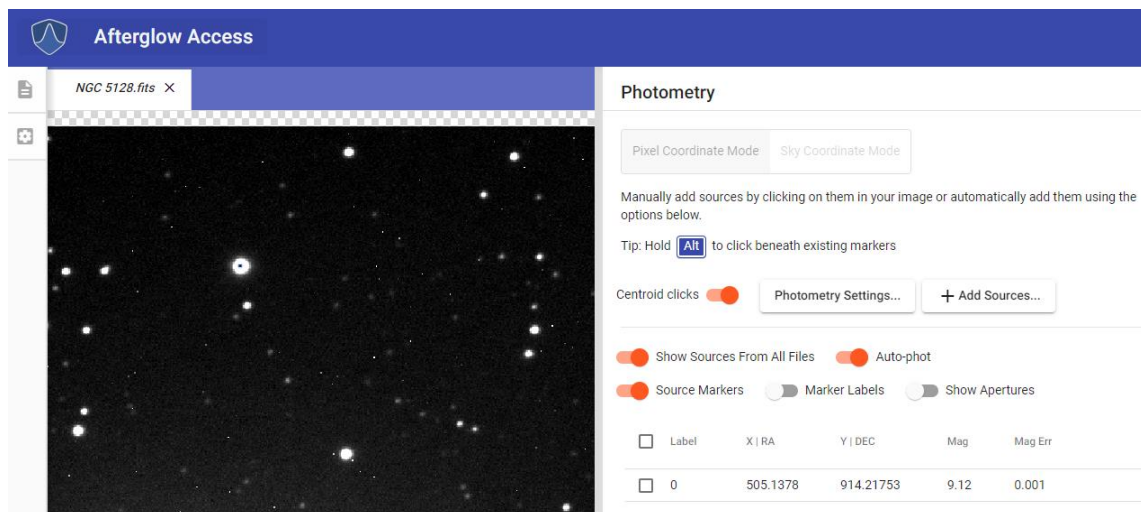
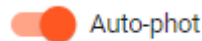
If the “**Centroid clicks**” toggle button is toggled on, which is the default, when the user clicks on a star, it will shift the selected starting point towards the point of the peak value.



If the “**Show Sources From All Files**” toggle button is toggled on, which is the default, the user will see all previous points the user has clicked on within a set of open images.



If the “**Auto-phot**” toggle button is toggled on, which is the default, AgA will automatically measure the brightness of a star or point selected on an image. In the example given, the star’s magnitude is estimated at 9.12 with an error of 0.001.



**Caption:** The left-hand portion of the image has an image of an irregular galaxy NGC 5128. The image is zoomed in to the top middle portion of the entire image of the galaxy. Therefore, there are no discernible features, except several stars. One of the stars that is located near the upper left-hand corner has a small blue dot on its center. The right half of the image shows the upper portion of the Photometry tool panel. One source is shown in the Photometry list. The source is the star that has the blue dot on it.

If the **“Source Markers”** toggle button is toggled on, which is the default, two other toggle buttons become available: **“Marker Labels”** and **“Show Apertures”**.



If the **“Marker Labels”** toggle button is toggled on, which is not the default, then each point or star the user has selected will be assigned a sequential number in the order they have been selected. The first one will be labeled 0, the second one will be labeled 1, and so on.

**Photometry**

Pixel Coordinate Mode Sky Coordinate Mode

Manually add sources by clicking on them in your image or automatically add them using the options below.

Tip: Hold **Alt** to click beneath existing markers

Centroid clicks ☒ Photometry Settings... [+ Add Sources...](#)

☒ Show Sources From All Files ☒ Auto-phot

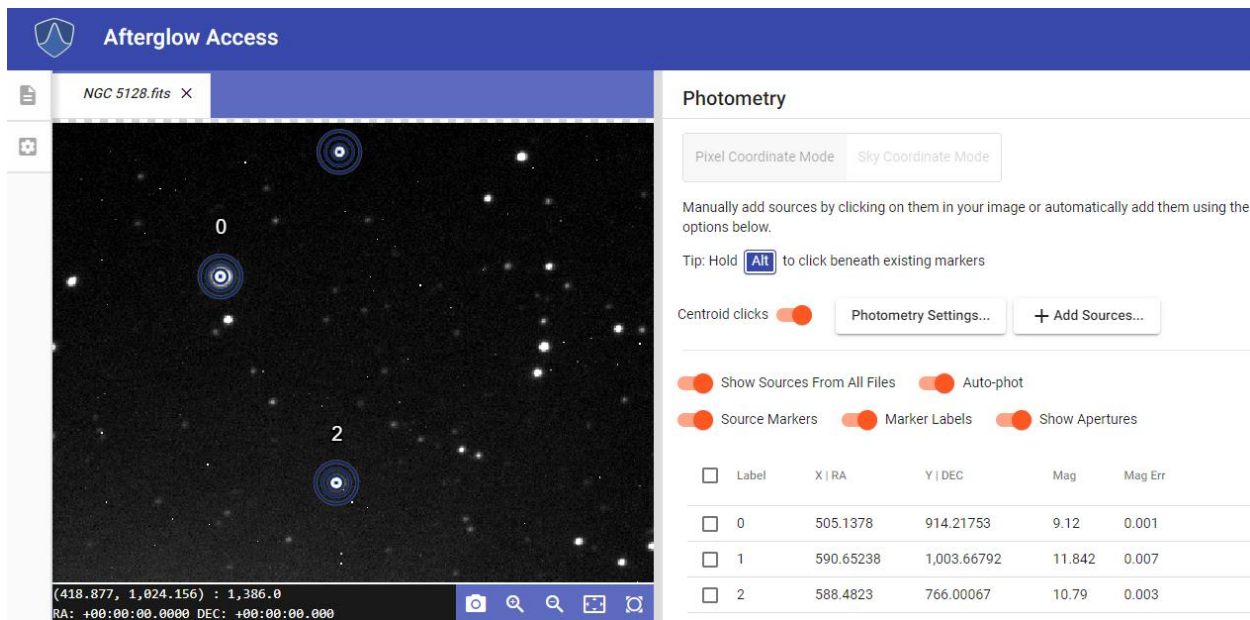
☒ Source Markers ☒ Marker Labels ☐ Show Apertures

<input type="checkbox"/>	Label	X   RA	Y   DEC	Mag	Mag Err
<input type="checkbox"/>	0	505.1378	914.21753	9.12	0.001
<input type="checkbox"/>	1	590.65238	1,003.66792	11.842	0.007
<input type="checkbox"/>	2	588.4823	766.00067	10.79	0.003

(648.626, 827.838) : 1,452.0  
RA: +00:00:00.0000 DEC: +00:00:00.000

**Caption:** The left-hand portion of the image has an image of an irregular galaxy NGC 5128. The image is zoomed in to the top middle portion of the entire image of the galaxy. Therefore, there are no discernible features, except several stars. Three of the stars have a small blue dot located on their centers. These same stars are also labeled 0, 1, and 2. The right half of the image shows the upper portion of the Photometry tool panel. Three sources are shown in the Photometry list. These are the sources that are labeled 0, 1, and 2.

The **“Show Apertures”** toggle button shows the area around the star or point used to calculate the magnitude. The default setting for this toggle button is off.



**Caption:** The left-hand portion of the image has an image of an irregular galaxy NGC 5128. The image is zoomed in to the top middle portion of the entire image of the galaxy. Therefore, there are no discernible features, except several stars. Three of the stars have a small blue dot located on their centers, and are surrounded by a blue circular outline. These same stars are also labeled 0, 1, and 2. The right half of the image shows the upper portion of the Photometry tool panel. Three sources are shown in the Photometry list. These are the sources that are labeled 0, 1, and 2.

Five other buttons are available at the bottom of the Photometry tool panel.



The first one is **Merge Selected Sources** and becomes available after selecting more than one source or star. The **Merge Selected Sources** button allows the user to tell AgA that two or more markers are representing the same source, such as a moving asteroid. Then, AgA will extrapolate or interpolate that source's position throughout the remaining images.



The second one is **Remove Selected Sources**, and it will remove the selected sources from the list of stars or points that the user has measured.



The third button, **Remove All Sources**, will remove all sources from the list. It is important to note that AgA will continue to count the number of sources. For example, if three sources have already been selected (number 0, 1, and 2), the next point that is selected will automatically be number 3. This occurs whether the previous points have been removed or not.



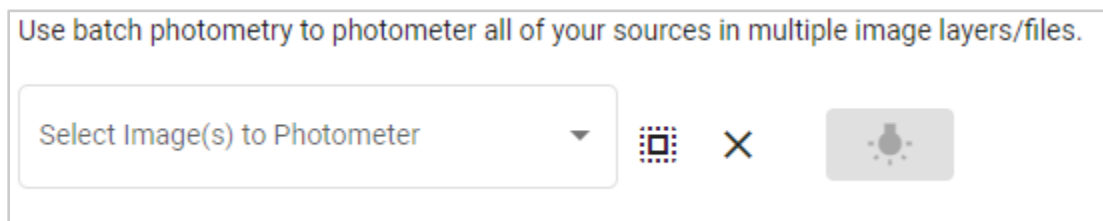
The fourth button is **Update Photometry**. If the user has changed any of the Photometry settings during their work, selecting this button will recalculate each source's magnitude.



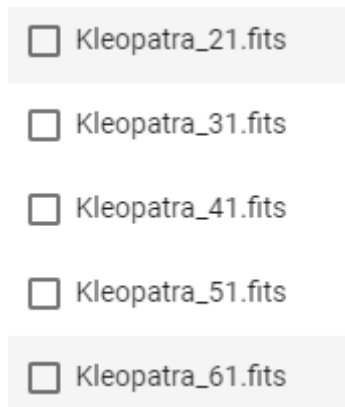
The fifth button is **Export Data**. If this button is selected, the user can download all of their current data to their computer. The data will be saved into a spreadsheet labeled `afterglow_sources`.



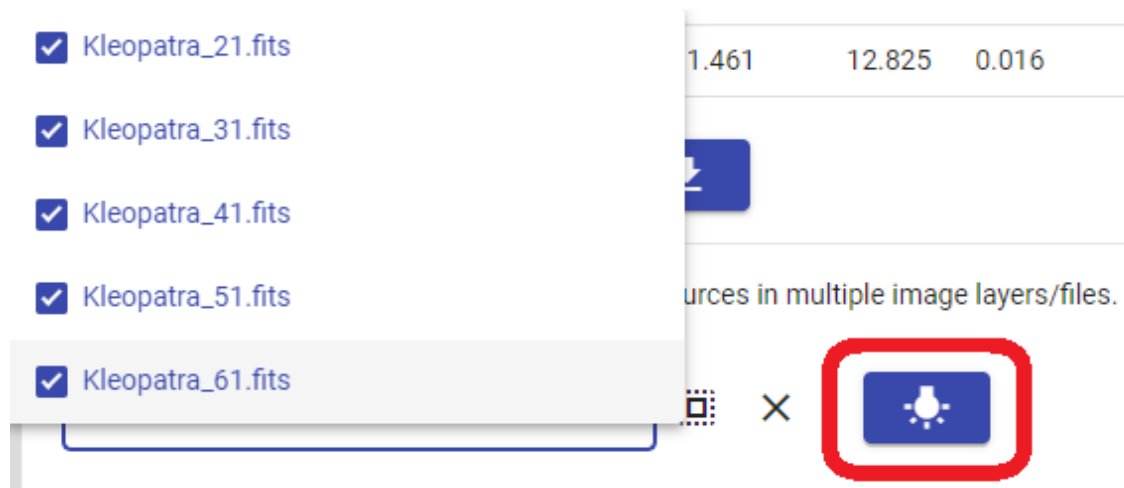
After a bit of practice with a single image, the user may want to try batch photometry if they are working with multiple images at the same time. This can be accomplished through the “**Select Image(s) to Photometer**” drop-down menu, which is located below the **Merge Selected Sources** button.



If the user clicks the drop-down menu, then they will see every image that they currently have open.

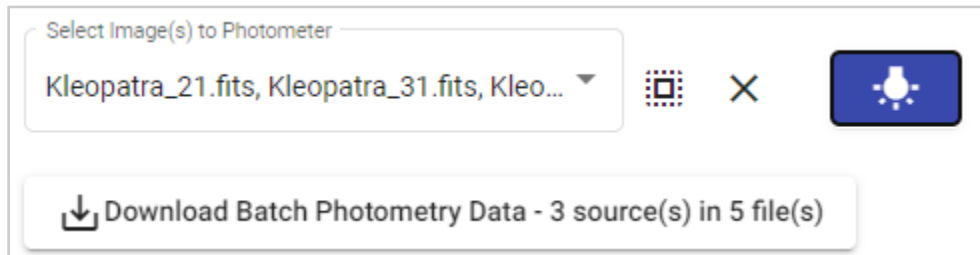


Once this drop-down menu is open, the user can select the images that they want their previously selected point sources measured in. If the user wants all of the images in their file library list photometered, then they can click on the icon (square with an outline of dots) to the right of the “**Select Image(s) to Photometer**” drop-down menu. If they want to deselect all of the files, they can click on the X icon to the right of this icon. Once the desired files are chosen, they can select the **Batch Photometry** button. This button is located to the right of the X icon.



**Caption:** The “**Select Image(s) to Photometer**” drop-down menu is shown on the left side of the image. The drop-down menu is open and five Kleopatra images are shown and selected. The **Batch Photometry** button is also outlined in red for added emphasis. This button is located near the bottom right of the image.

After this button is selected, another button will be available below the drop-down menu. This allows the user to download their new data to their computer.



## PIXEL OPERATIONS

### Keyboard Shortcut “\*”

The Pixel Operations tool allows the user to perform certain arithmetic and mathematical operations to an image on a per-pixel basis.



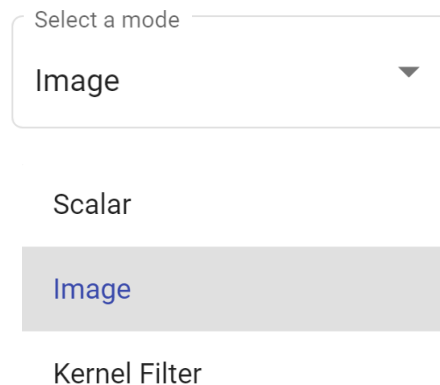
### Simple Settings

There are two settings options within the Pixel Operations tool. The default is Simple settings.



### Select a Mode

The “**Select a mode**” drop-down menu allows the user to choose between three different modes. From top to bottom, these modes are Scalar, Image, and kernel Filter.



**Caption:** Shown above is the “**Select a mode**” drop-down menu in the Simple Settings of the Pixel Operations tool. The options available in the list, from top to bottom, are Scalar, Image, and Kernel Filter.

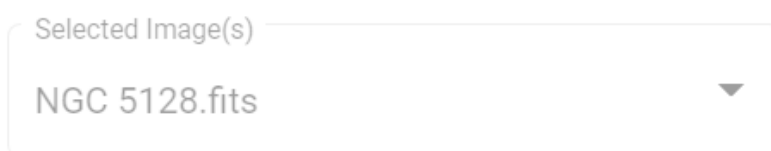
## Image Mode

The Image mode allows the user to perform simple arithmetic on two images. It is the default mode in Simple settings.



## Selected Image(s) Drop-Down Menu

The “**Selected Image(s)**” drop-down menu is not a typical drop-down menu. This menu is automatically filled in based on the image that is currently open in the display window. For example, if the user currently has NGC 5128.fits in the AgA display window, this will be the file in this drop-down menu.



## Additional Image(s) Drop-Down Menu

The “**Additional Image(s)**” drop-down menu allows the user to select other images that they want the specified arithmetic performed on. The user can choose from any files that are currently open in their file library list.



If the user wants to perform the arithmetic on all of the images in their file library list, they can click on the icon (square with an outline of dots) to the right of the “**Additional Image(s)**” drop-down menu.



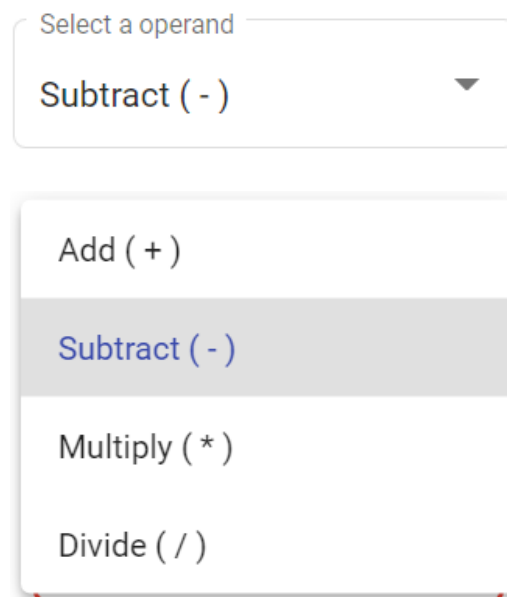


If the user wants to remove all of their selected images, they can click on the X icon that is to the right of the “**Additional Image(s)**” drop-down menu.



### Select an Operand Drop-Down Menu

The “**Select an Operand**” drop-down menu allows the user to select the operation that they would like performed on every image. The four operands, from top to bottom, are Add, Subtract, Multiply,” and Divide. As the name of the tool suggests, this operation is performed on a per-pixel basis, and it is repeated for every single pixel.



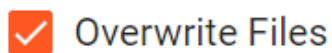
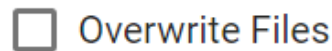
For example, imagine that a certain pixel in the image that is currently displayed has a value of 6. The pixel located in the same position in the image selected in the drop-down menu described below has a value of 2. If “Add” is selected, the pixel in the same location in the new image will have a value of  $6 + 2 = 8$ . If “Subtract” is selected, the pixel in the same location in the new image will have a value of  $6 - 2 = 4$ . If “Multiply” is selected, the pixel in the same location in the new image will have a value of  $6 * 2 = 12$ . If “Divide” is selected, the pixel in the same location in the new image will have a value of  $6 / 2 = 3$ .

## Select an Image Drop-Down Menu

The “**Select an Image**” drop-down menu allows the user to choose the image that will be used in the various operations.



To the right of this drop-down menu is the **Overwrite Files** button. The default for this button is off. If this button is off, then new files will be created with the pixel operations.



For example, if one file was selected in the “**Additional Image(s)**” drop-down menu, then two new files will be created: one for the operation that occurred with the file automatically selected in the “**Selected Image(s)**” drop-down menu and the file in the “**Select an Image**” drop-down menu, and one for the operation that occurred between the file in the “**Additional Image(s)**” drop-down menu and the file in the “**Select an Image**” drop-down menu. If the **Overwrite Files** button is selected, then the files in the “**Selected Image(s)**” and “**Additional Image(s)**” drop-down menus (the original files) will be modified.

For example, imagine that the user currently has the file NGC 5128.fits open. This means that this file is the file selected in the “**Selected Image(s)**” drop-down menu. They also have selected Kleopatra\_01.fits in the “**Additional Image(s)**” drop-down menu. They also have selected Add as their operand. They have selected Kleopatra\_61.fits as the file in the “**Select an Image**” drop-down menu, and the **Overwrite Files** button is not selected. Two new files will be created. The first file will be the image that results when Kleopatra\_61.fits is added to NGC 5128.fits. The second file will be the image that results when Kleopatra\_61.fits is added to Kleopatra\_01.fits.

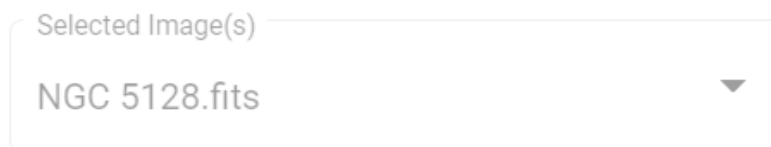
### Scalar Mode

The Scalar mode allows the user to perform simple arithmetic between an image and a scalar value (any real number). It is the first mode on the “**Select a Mode**” drop-down menu.



### Selected Image(s) Drop-Down Menu

The “**Selected Image(s)**” drop-down menu is not a typical drop-down menu. This menu is automatically filled in based on the image that is currently open in the display window. For example, if the user currently has NGC 5128.fits in the AgA display window, this will be the file in this drop-down menu.



### Additional Image(s) Drop-Down Menu

The “**Additional Image(s)**” drop-down menu allows the user to select other images that they want the specified arithmetic performed on. The user can choose from any files that are currently open in their file library list.



If the user wants to perform the arithmetic on all of the images in their file library list, they can click on the icon (square with an outline of dots) to the right of the “**Additional Image(s)**” drop-down menu.



If the user wants to remove all of their selected images, they can click on the X icon that is to the right of the “**Additional Image(s)**” drop-down menu.



### Select an Operand Drop-Down Menu

The “**Select an Operand**” drop-down menu allows the user to select the operation that they would like performed on every image. The four operands, from top to bottom, are Add, Subtract, Multiply, and Divide. As the name of the tool suggests, this operation is performed on a per-pixel basis, and it is repeated for every single pixel.

Select a operand

Subtract ( - )

Add ( + )

Subtract ( - )

Multiply ( \* )

Divide ( / )

For example, imagine that a certain pixel in the image that is currently displayed has a value of 6. The scalar value specified in the box described below is 2. If “Add” is selected, the pixel in the same location in the new image will have a value of  $6 + 2 = 8$ . If “Subtract” is selected, the pixel in the same location in the new image will have a value of  $6 - 2 = 4$ . If “Multiply” is selected, the pixel in the same location in the new image will have a value of  $6 * 2 = 12$ . If “Divide” is selected, the pixel in the same location in the new image will have a value of  $6 / 2 = 3$ .

### Specify a Scalar Value Box

The Specify a Scalar Value box allows the user to choose their scalar value. This value can be positive or negative, and it can include decimal points.

A rectangular box with a red border and the text "Specify a scalar value" in red.

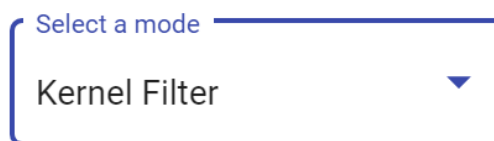
To the right of this box is the **Overwrite Files** button. The default for this button is off. If this button is not selected, then the resulting images will be added to the user's file library. If this button is selected, then the user's original files will be modified.

☐ Overwrite Files

☒ Overwrite Files

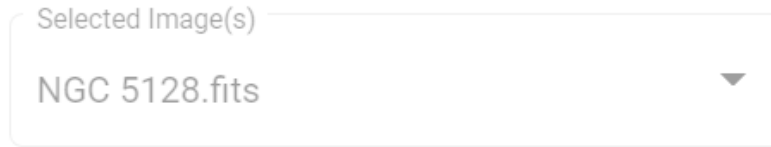
### Kernel Filter

The Kernel Filter mode allows the user to apply a variety of Kernel Filters to an image. It is the third and final mode on the "**Select a Mode**" drop-down menu.

A drop-down menu with a blue border. The text "Select a mode" is at the top in blue. Below it, "Kernel Filter" is displayed, followed by a small blue downward-pointing triangle.


### Selected Image(s) Drop-Down Menu

The "**Selected Image(s)**" drop-down menu is not a typical drop-down menu. This menu is automatically filled in based on the image that is currently open in the display window. For example, if the user currently has NGC 5128.fits in the AgA display window, this will be the file in this drop-down menu.

A light gray rounded rectangular box with a thin border. Inside, the text "Selected Image(s)" is at the top in a small, light gray font. Below it, "NGC 5128.fits" is displayed in a larger, dark gray font. A small dark gray downward-pointing triangle is on the right side of the box.

### Additional Image(s) Drop-Down Menu

The “**Additional Image(s)**” drop-down menu allows the user to select other images that they want the specified Kernel Filter applied to. The user can choose from any files that are currently open in their file library list.

A light gray rounded rectangular box with a thin border. Inside, the text "Additional Image(s)" is displayed in a dark gray font. A small dark gray downward-pointing triangle is on the right side of the box.

If the user wants to apply the kernel filter to all of the images in their file library list, they can click on the icon (square with an outline of dots) to the right of the “**Additional Image(s)**” drop-down menu.



If the user wants to remove all of their selected images, they can click on the X icon that is to the right of the “**Additional Image(s)**” drop-down menu.



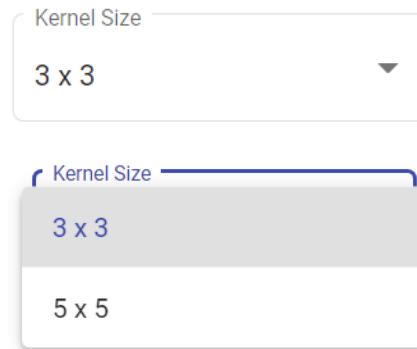
### Kernel Filter Drop-Down Menu

The “**Kernel Filter**” drop-down menu allows the user to choose which Kernel Filter they would like to apply to the image. The default Kernel Filter is Median. Kernel Filters can be used for specific purposes, such as blurring and sharpening. If you want to learn more about the various Kernel Filters that can be applied, please visit <https://docs.scipy.org/doc/scipy/reference/ndimage.html> for more information.

A light gray rounded rectangular box with a thin border. Inside, the text "Kernel Filter" is at the top in a small, light gray font. Below it, "Median" is displayed in a larger, dark gray font. A small dark gray downward-pointing triangle is on the right side of the box.

## Kernel Size Drop-Down Menu

The “**Kernel Size**” drop-down menu allows the user to choose the size of their Kernel Filter. The default Kernel Size is 3 x 3, and the only other option is 5 x 5.



To the right of this box is the **Overwrite Files** button. The default for this button is off. If this button is not selected, then the resulting images will be added to the user’s file library. If this button is selected, then the user’s original files will be modified.

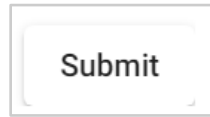
☐ Overwrite Files

☒ Overwrite Files

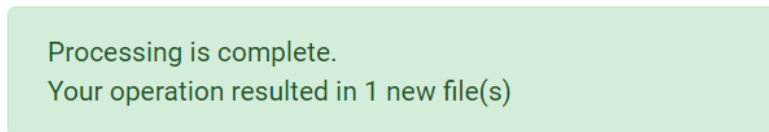
Essentially, a Kernel Filter, like the other modes, changes the values of individual pixels. The specific Kernel Filter specifies how the pixels will be changed. Imagine that the defaults for the previous drop-down menus are selected: median and 3 x 3. In this scenario, the median Kernel Filter will take the specific pixel that is being modified and center it in a 3 x 3 grid. The filter will look at the values of each of the pixels in this 3 x 3 grid, and arrange them in ascending order. It will then take the median value (the value in the middle), and assign that value to the pixel. It will then repeat this process on a per-pixel basis for the rest of the image.

## Submit

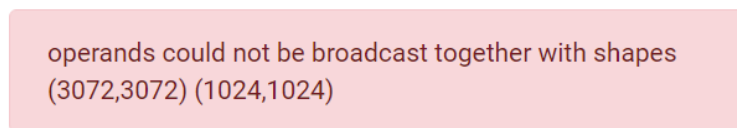
Once the user is satisfied with their selections, they can select the **Submit** button to actually perform the pixel operations.



If this process was successful, a green dialogue box will appear at the bottom of the Pixel Operations tool panel. It will state, "Processing is complete."



If this process was not successful, a red dialogue box will appear at the bottom of the Pixel Operations tool panel. An example of an error that would cause this unsuccessful processing is if the user tries to perform simple arithmetic on two images that are not the same size in the Image mode.



## Advanced Settings

Using the Advanced Settings, a user can process complex batch data. For example, this is a way that the user can perform one long string of operations on the image at one time. The user is encouraged to explore all of the options in the Advanced Settings, but for the purposes of this manual, they will not be explained.





## WCS CALIBRATION

### Keyboard Shortcut “w”

The WCS Calibration tool is an AgA tool that allows users to add right ascension and declination to some non-WCS images.



WCS stands for World Coordinate System. This system maps the pixels in the data to the right ascension and declination coordinates in the night sky. The WCS Calibration tool uses an algorithm that compares the relative positions of stars to a database. Therefore, there needs to be enough stars in the image in order for the algorithm to work. For more information about the World Coordinate System and how the algorithm works, visit [astrometry.net](http://astrometry.net).

**Caption:** When the WCS Calibration tool is opened, this is the initial view of the WCS Calibration tool panel. There is the **“Select Image(s) to Calibrate”** Drop-Down Menu located on the top. Beneath this is the **Extract Values from Current Viewer** button. Underneath this button are different values that guide the WCS calibration. Finally, beneath these values are the **Open Source Extraction Settings** button and the **Submit** button.

## Select Image(s) to Calibrate Drop-Down Menu

The first drop-down menu for the WCS Calibration tool is “**Select Image(s) to Calibrate**”. In this drop-down menu, it gives the user the option to choose any of the images that are uploaded to their file library list. To choose the images, select the drop-down menu, then click on the files to be calibrated. Once an image is selected, the box to the left of it will turn blue with a white checkmark and the text of the image will also turn blue. If the user wishes to deselect an image, simply click on it again.

If the user wants to calibrate all of the images in their file library list, click on the icon (square with an outline of dots) to the right of the “**Select Image(s) to Calibrate**” drop-down menu.



If the user wants to remove all of the selected images, click on the X icon that is to the right of the “**Select Image(s) to Calibrate**” drop-down menu.



## Extract Values from Current Viewer Button

The button directly underneath the “**Select Image(s) to Calibrate**” drop-down menu is the **Extract Values From Current Viewer** button. Once selected, the information below this button is automatically filled in based on the image that is currently in the display window. In order for this button to appear, there must be an image currently open in the display window. The user can start the algorithm blind; however, if this button is selected, it fills in some of the boxes with information from the image’s file information header. The information that is given provides the center for the search.



Extract values from current viewer

## RA (Hours) and Dec (Degs) Boxes

The RA (hours) and Dec (Degs) boxes allow for the input of right ascension and declination for the algorithm. If the image is already WCS-calibrated, when the user clicks on the **Extract Values from Current Viewer** button, these boxes will

automatically have the RA and Dec of the image. As stated, the RA is listed in hours, minutes, and seconds, and the Dec is listed in degrees, minutes, and seconds.

If the user knows the approximate RA and Dec for the image, then they can enter this information and it gives the algorithm a starting search point. Essentially, it acts as the center of the search.

RA (hours)	Dec (deg)
------------	-----------

### Radius (Degs) Box

The Radius (deg) box allows for the input of the search radius around the indicated RA and Dec of the image.

Radius (deg)
1

### Max Sources Box

The Max Sources box limits the number of sources entering the algorithm. It helps decrease the search time if the image has many sources, like a globular cluster.

Max Sources
100

### Min Scale (arcsec/pixel) and Max Scale (arcsec/pixel) Boxes

The Min Scale (arcsec/pixel) and Max Scale (arcsec/pixel) boxes allow the user to choose the estimated scale of the image. Given the image, these values may be chosen when the user clicks on the **Extract Values from Current Viewer** button.

The Min Scale (arcsec/pixel) box controls the minimum number of arcsecs that can be present in each pixel. Similarly, the Max Scale (arcsec/pixel) box controls the maximum number of arcsecs that can be present in each pixel.

Both of these boxes control the size of the triangles used in the algorithm.

Min Scale (arcsec/pixel)	Max Scale (arcsec/pixel)
0.531	0.649

## Open Source Extraction Settings Button

The **Open Source Extraction Settings** button opens the source extraction settings. The user is free to explore these settings, but for the purposes of this manual, they will not be explained.



Open Source Extraction Settings...

---

## Submit Button

Once the user is satisfied with the information inputted in each box, the user can select the **Submit** button to start the calibration process. Once this button is selected, the user will receive a pop-up that says that the WCS Calibration is completed. It will either say that a solution was found or that it failed to find a solution. If it failed to find a solution, then RA and Dec were not added to the image.



Submit

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## ALIGNER

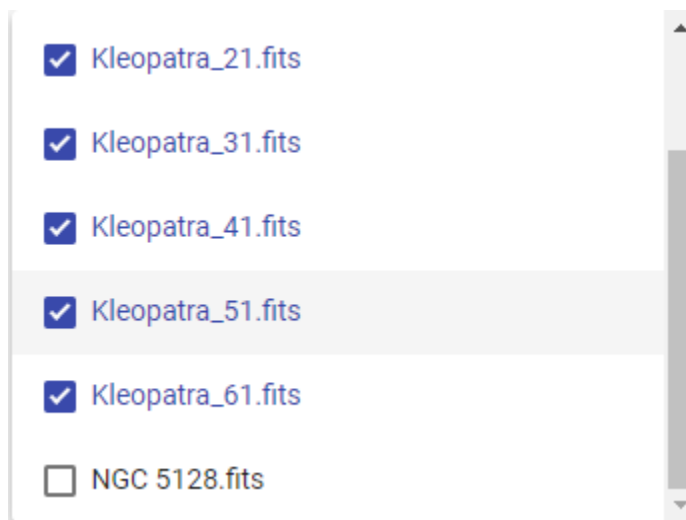
### Keyboard Shortcut “a”

The Aligner is an AgA tool that allows the users to take a selected group of similar images and align or position them with regard to one of the previously selected images. Currently, the only option is to align them astrometrically. In other words, the right ascension and declination of these images will be matched so that each pixel represents the same position in the night sky.



### Select Image(s) to Align Drop-Down Menu

The first drop-down menu for the aligning tool is “**Select Image(s) to Align**”. In this drop-down menu, it gives the user the option to choose any of the images that are uploaded to their file library list. To choose the images, select the drop-down menu, then click on the files to be aligned. Once an image is selected, the box to the left of it will turn blue with a white checkmark and the text of the image will also turn blue (reference the image below). If the user wishes to deselect an image, simply click on it again.



If the user wants to align all of the images in their file library list, click on the icon (square with an outline of dots) to the right of the **“Select Image(s) to Align”** drop-down menu.



If the user wants to remove all of the selected images, click on the X icon that is to the right of the **“Select Image(s) to Align”** drop-down menu.



### Reference Image File Drop-Down Menu

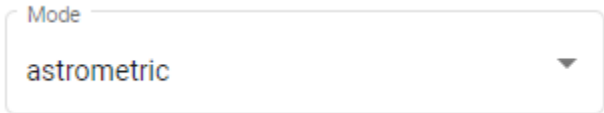
The second drop-down menu is **“Reference Image File”**. It is located directly beneath the **“Select Image(s) to Align”** drop-down menu. This drop-down menu allows the user to choose only one image, and the only options are the images that have been chosen in the **“Select Image(s) to Align”** drop-down menu. The image that is chosen in this drop-down menu is the image that all of the other images will be aligned to.

A screenshot of a drop-down menu with the text "Reference Image File" and a downward arrow on the right side.

Reference Image File

### Mode Drop-Down Menu

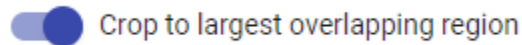
The third drop-down menu is **“Mode”**. It is located directly beneath the **“Reference Image File”** drop-down menu. Currently, the only option for the **“Mode”** drop-down is astrometric. This mode means that it aligns the right ascension and declination values of the pixels using the image’s WCS calibration. For more information on WCS calibration, reference the glossary, the WCS Calibration section, or the WCS subsection of the File Info section.

A screenshot of a drop-down menu with the text "Mode" above "astrometric" and a downward arrow on the right side.

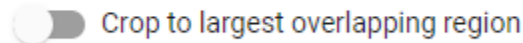
Mode  
astrometric

## Crop to Largest Overlapping Region Toggle Button

Directly below the “**Mode**” drop-down menu is the “**Crop to Largest Overlapping Region**” toggle button. The default for this button is on. When this button is toggled on, it will crop to the largest shared area of right ascension and declination.

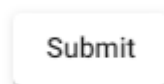


When this button is toggled off, each image is cropped to a slightly different size. The reference remains uncropped, but each of the other images are cropped so that the right ascension and declination are located in the same pixel position. This is what creates the slightly different image dimensions.

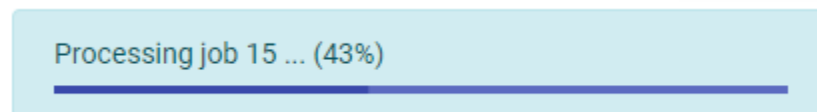


## Submit Button

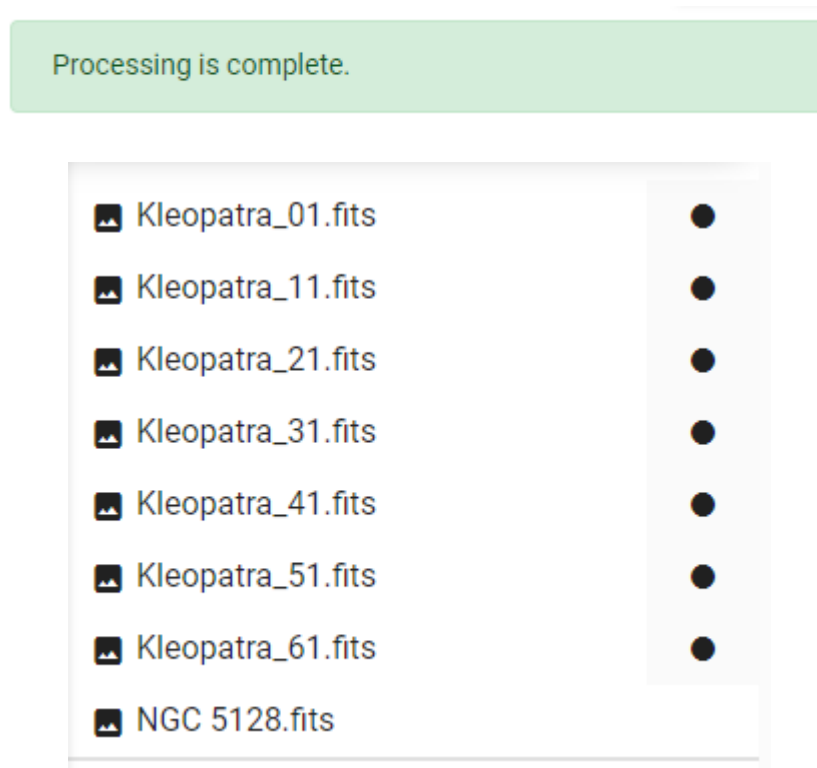
Once the user has selected the images that they want aligned, and have also chosen the reference image, they can align the images using the **Submit** button. This button is located beneath the “**Crop to Largest Overlapping Region**” toggle button. The user will not be able to click on this button if the first two drop-down menus do not contain images.



The user will know that AgA is processing the request once a loading bar appears beneath the **Submit** button.



Moreover, the user will know that the request has been completed once the loading bar has the message “Processing is complete” and bullet points appear to the right of each selected image in the file library list (on the left-hand side of the AgA window).



It is important to note that for the above image of the file library list, all of the Kleopatra files would be aligned to one of the Kleopatra images. Additionally, the “**Crop to Largest Overlapping Region**” toggle button would have been on because each image has a circle to the right of its name. However, if this was toggled off, then the reference image would not have had a circle to the right of its name.



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## STACKER

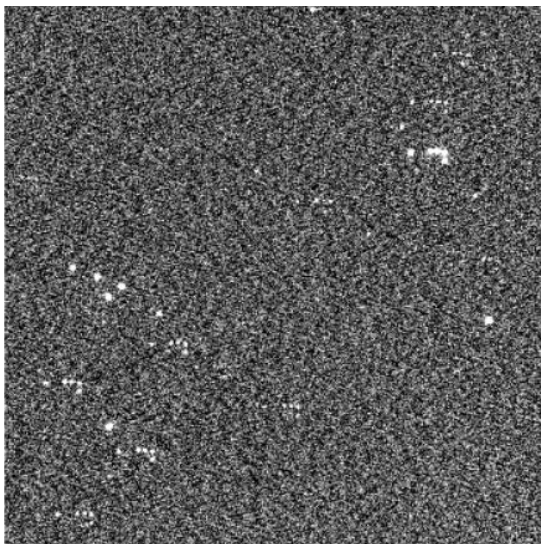
### Keyboard Shortcut “shift + S”

The Stacker is an AgA tool that allows the user to combine multiple images into a single image.



Before utilizing the Stacker tool, it is most beneficial to align the images using the Aligner tool. This will ensure that the same object, like a star (which should be stationary), will not appear multiple times in the image.

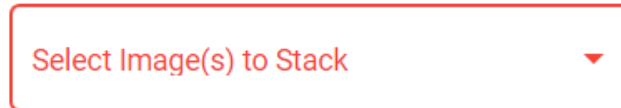
For example, the image below shows seven Kleopatra images stacked without using the Aligner tool. Notice how the star appears multiple times in the image, even though Kleopatra should be the only moving object.



**Caption:** Shown above is the stacked image of asteroid Kleopatra. The images were not aligned prior to stacking. Therefore, the star in the image appears multiple times in the upper right-hand corner.

## Select Image(s) to Stack Drop-Down Menu

The “**Select Image(s) to Stack**” drop-down menu allows the user to select the images that they want to stack.



If the user wants to stack all of the images in their file library list, they can click on the icon (square with an outline of dots) to the right of the “**Select Image(s) to Stack**” drop-down menu.

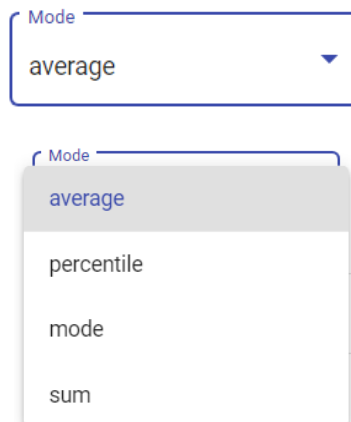


If the user wants to remove all of their selected images, they can click on the X icon that is to the right of the “**Select Image(s) to Stack**” drop-down menu.



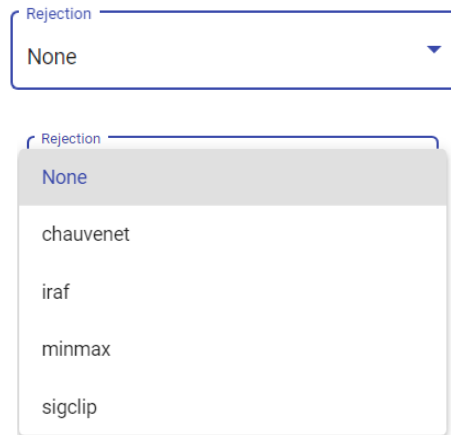
## Mode Drop-Down Menu

The “**Mode**” drop-down menu allows the user to choose the mode that will be used during the stacking. The mode determines how the values of the same pixel in each image will be combined into a single value. The default mode is average, which averages the values from each image to create a single value. There are three other modes, and they are percentile, mode, and sum. The user is encouraged to explore the differences between these modes.



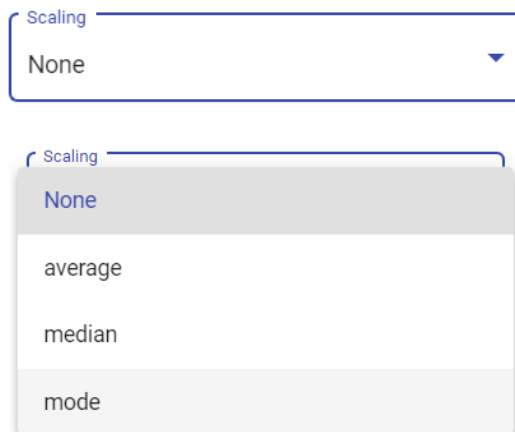
## Rejection Drop-Down Menu

The “**Rejection**” drop-down menu allows the user to choose how certain pixel values are rejected before they are combined. It essentially specifies whether any of the values need to be disregarded from the combination. The default rejection type is none, which means that no rejection is occurring. There are four types of rejection: chauvenet, iraf, minmax, and sigclip. The user is encouraged to explore the differences between these rejection types.



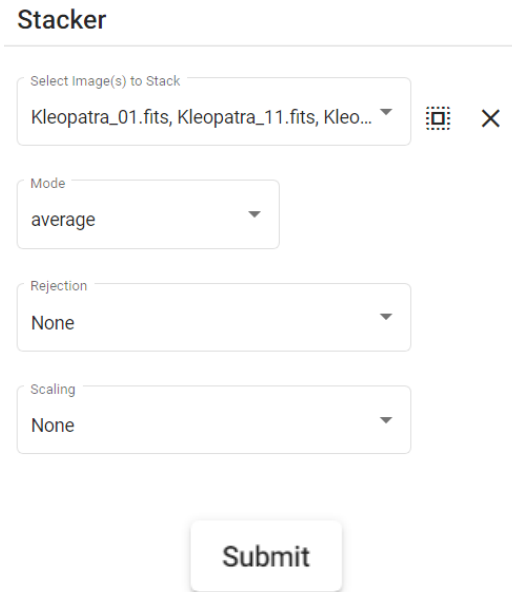
## Scaling Drop-Down Menu

The “**Scaling**” drop-down menu allows the user to choose how certain pixel values are scaled as they are combined. Scaling is a way to shift the values so they are normalized, or on the same level. The default scaling type is none, which means that no scaling is occurring. There are three types of scaling: average, median, and mode. The user is encouraged to explore the differences between these scaling types.



## Submit Button

Once the user has chosen the images that they want to stack and selected their wanted mode, rejection, and scaling type, they can select the **Submit** button.



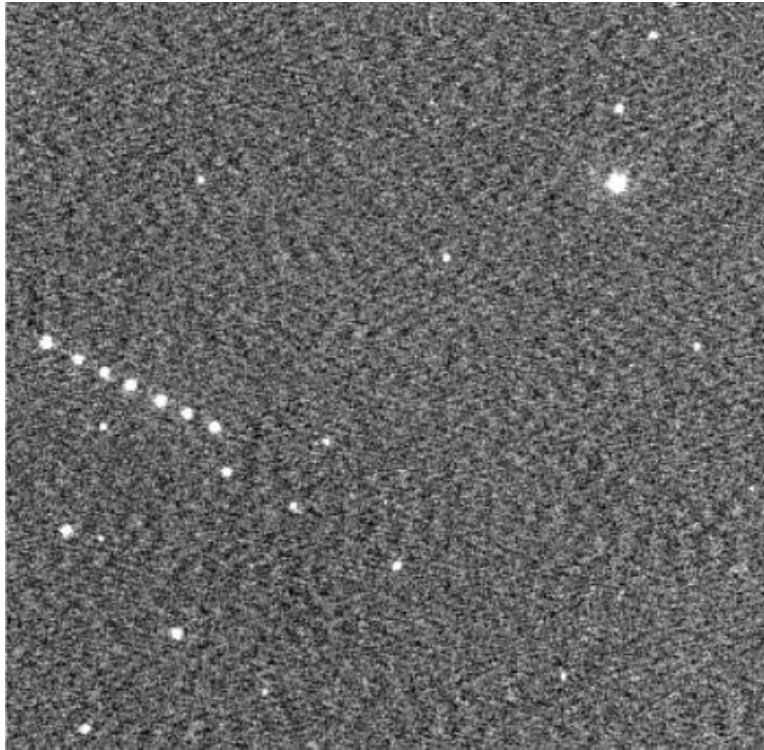
The screenshot shows a web interface titled "Stacker". It contains four dropdown menus and a "Submit" button. The first dropdown, "Select Image(s) to Stack", shows a list of files: "Kleopatra\_01.fits, Kleopatra\_11.fits, Kleo...". To its right are icons for a grid and a close button (X). The second dropdown, "Mode", is set to "average". The third dropdown, "Rejection", is set to "None". The fourth dropdown, "Scaling", is set to "None". Below these is a large "Submit" button.

**Caption:** Above is an example of the settings that could be used to stack multiple images of Kleopatra (the files ending in 01, 11, 21, 31, 41, 51, and 61) and the **Submit** button. These images are in the “**Select Image(s) to Stack**” drop-down menu. Average is selected in the “**Mode**” drop-down menu, and no rejection or scaling types are selected.

If the images stack successfully, then a green dialogue box will appear beneath the **Submit** button. It will state, “Processing is complete.” The new stacked image will appear in the user’s file library list.

Processing is complete.

Below is a picture of a successfully aligned and stacked image of seven asteroid Kleopatra files.



**Caption:** Above is a stacked image of seven asteroid Kleopatra images. There are several stars throughout the image. There are also seven dots that form a diagonal line near the middle left-hand side of the image. Each of the dots represents Kleopatra, and it showcases how Kleopatra moves across the sky.

As an additional way to experience and enjoy the stacked images, open the stacked image file in the Sonification tool.

## LINKS TO RESOURCES

Here are several additional resources that could be helpful for using and understanding AgA.

- AgA Demonstration:  
<https://us02web.zoom.us/rec/share/xmakw57iG6hcxGgDGazj2Em7OXpyR9yADdBhH6AVnkp-ln2sUjC0GPPyEw1qZBm7.jjFRwx4257c0A90u>
- AgA Video Tutorials: <https://www.youtube.com/watch?v=1J7Djv510-E&list=PLy034wwN98YlybjCMuF0Fd7flo62C9jYZ&index=4>
- Accessible AgA Video Tutorials:  
<https://www.youtube.com/user/introastro/playlists>
- IDATA Website:  
<https://idataproject.org/>
- Kernel Filter Definitions:  
<https://docs.scipy.org/doc/scipy/reference/ndimage.htm>
- WCS Calibration Information:  
[astrometry.net](http://astrometry.net)

# 15

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## GOING DEEPER

The purpose of the following Going Deeper sections is to help guide the user through specific activities that reinforce their understanding of the different AgA tools.

## 15-a

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### Display Settings: Going Deeper

This Going Deeper activity will utilize and compare the differences between the brightness presets found in the Display Settings tool. As a reminder, these presets are **Default**, **Faint Target**, and **Bright Target**. Ultimately, this activity will answer the question, “How can using various brightness presets alter the way an image is viewed?”

#### The Needed Files

If more guidance is needed on opening a file, see the “Files and the File Library List” section above.

Open the NGC 5128.fits file:

1. Click on the **Open Files** button.
2. Select the Sample folder.
3. Select the Deep Sky Objects folder.
4. Select the NGC 5128.fits file.

Next, open the Kleopatra\_01.fits file:

1. Click on the **Open Files** button.
2. Select the Sample folder.
3. Select the Solar System folder.
4. Select the Asteroid 216 Kleopatra folder. There should be 68 images in this folder.
5. Select the Kleopatra\_01.fits file.

Finally, open the Trifid Nebula.fits file:

1. Click on the **Open Files** button.
2. Select the Sample folder.
3. Select the Deep Sky Objects folder.
4. Select the Trifid Nebula.fits file.

#### The Assigned Presets

Now that all of the needed files are in the file library list, open the Display Settings tool. Ensure that the image of NGC 5128 is being viewed with the **Default** brightness preset. Additionally, select the **Bright Target** button for the Kleopatra file and the **Faint Target** button for the image of the Trifid Nebula. The **Default** brightness preset was chosen for NGC 5128 because it allows the user to see the details of the image most clearly. The

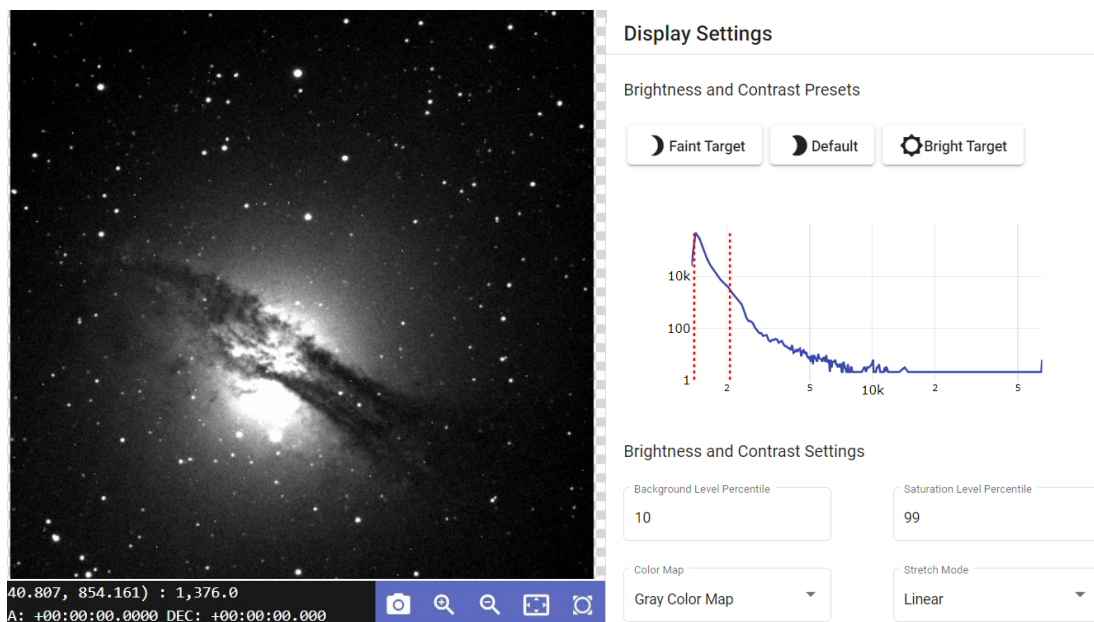


**Bright Target** preset was chosen for the Kleopatra file because it helps reduce some of the noise in the image, and it makes it easier to locate Kleopatra in the image. The **Faint Target** preset was chosen for the Trifid Nebula because it highlighted and accentuated the gas structure in the image.

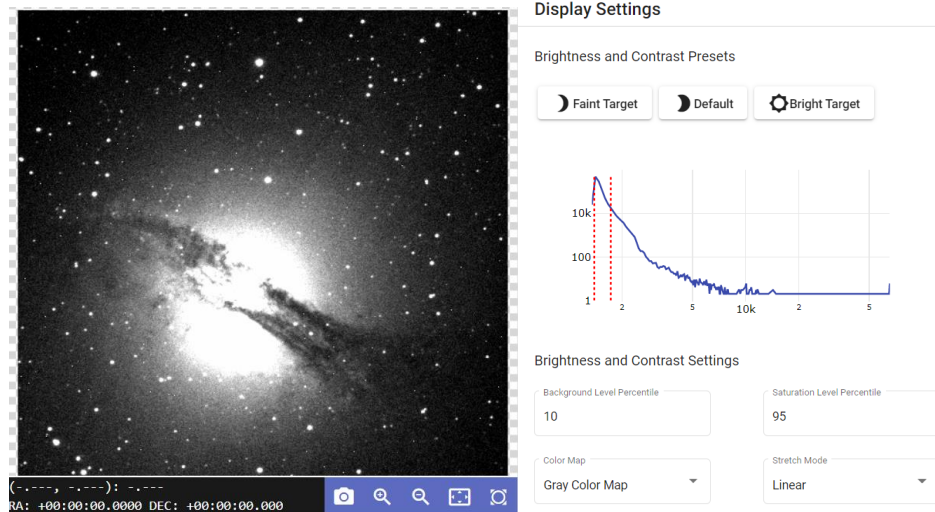
The next part of this Going Deeper section will walk the user through one comparison of the various display settings. However, before reading the next section, the user is encouraged to briefly explore and compare the various images in the other settings that are available outside of the assigned setting above. Try to observe how the assigned setting highlights the image's features allowing for more detailed observations to be made.

### Comparing Brightness Presets

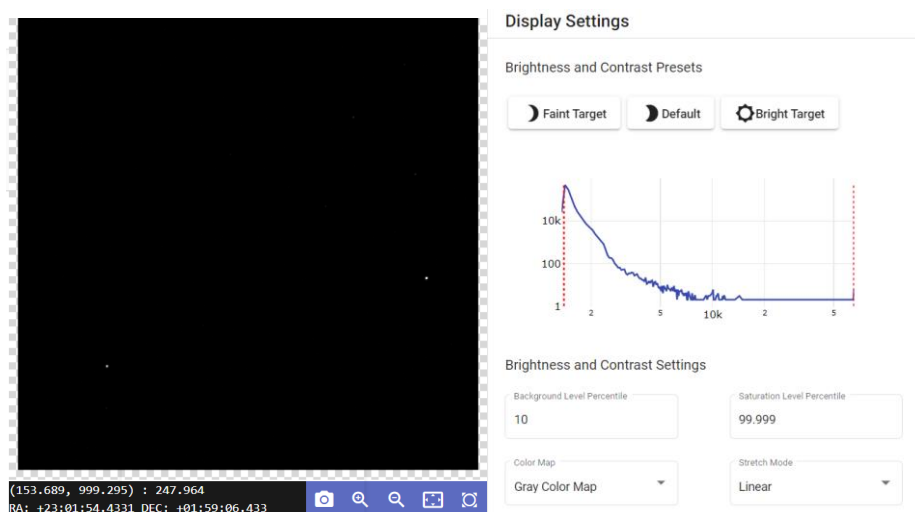
Below are three images of NGC 5128 in the three different brightness presets. Observe how the assigned preset allows for the most discernible interpretation of the galaxy's gas disk and bright center.



**Caption:** Shown above is NGC 5128 in the assigned **Default** setting. The left-hand portion of the image has an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The right half of the image has a histogram. The x-axis represents the brightness, or intensity, of a pixel. The y-axis represents the number of pixels at the given brightness.



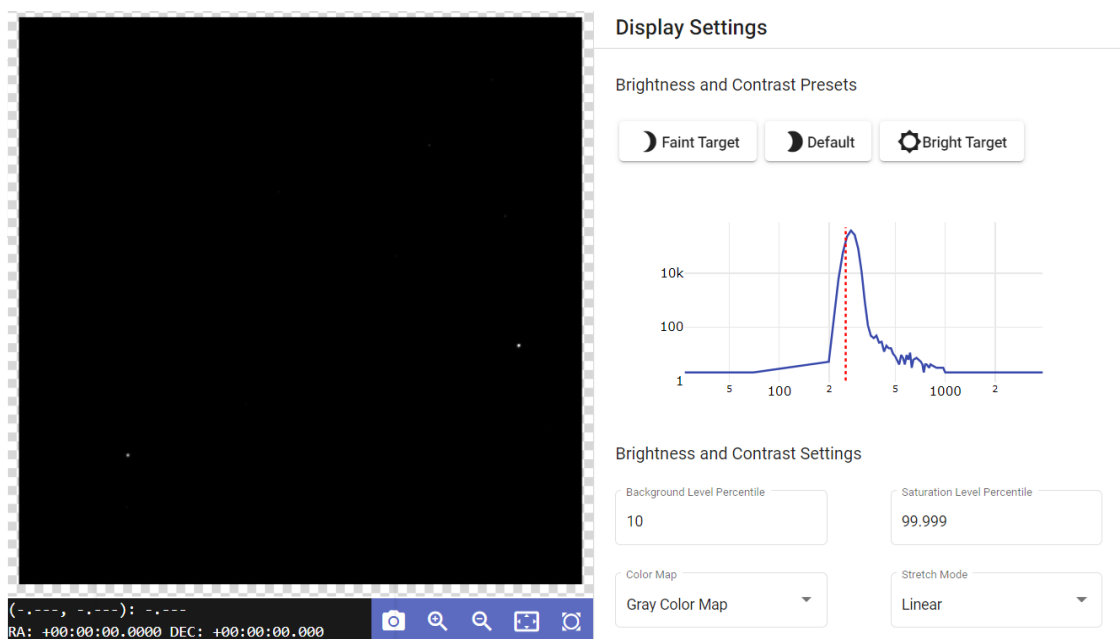
**Caption:** Shown above is NGC 5128 in the **Faint Target** setting, which displays the gas disk in less detail than the assigned setting. The left-hand portion of the image has an image of an irregular galaxy NGC 5128. The image has a gas disk stretching from the left middle to the lower right with a brighter sphere in the middle. The right half of the image has a histogram. The x-axis represents the brightness, or intensity, of a pixel. The y-axis represents the number of pixels at the given brightness.



**Caption:** Shown above is NGC 5128 in the **Bright Target** setting. The left-hand portion of the image has an image of an irregular galaxy NGC 5128. Due to the brightness display setting, only two stars are visible in the image. The right half of the image has a histogram. The x-axis represents the brightness, or intensity, of a pixel. The y-axis represents the number of pixels at the given brightness.

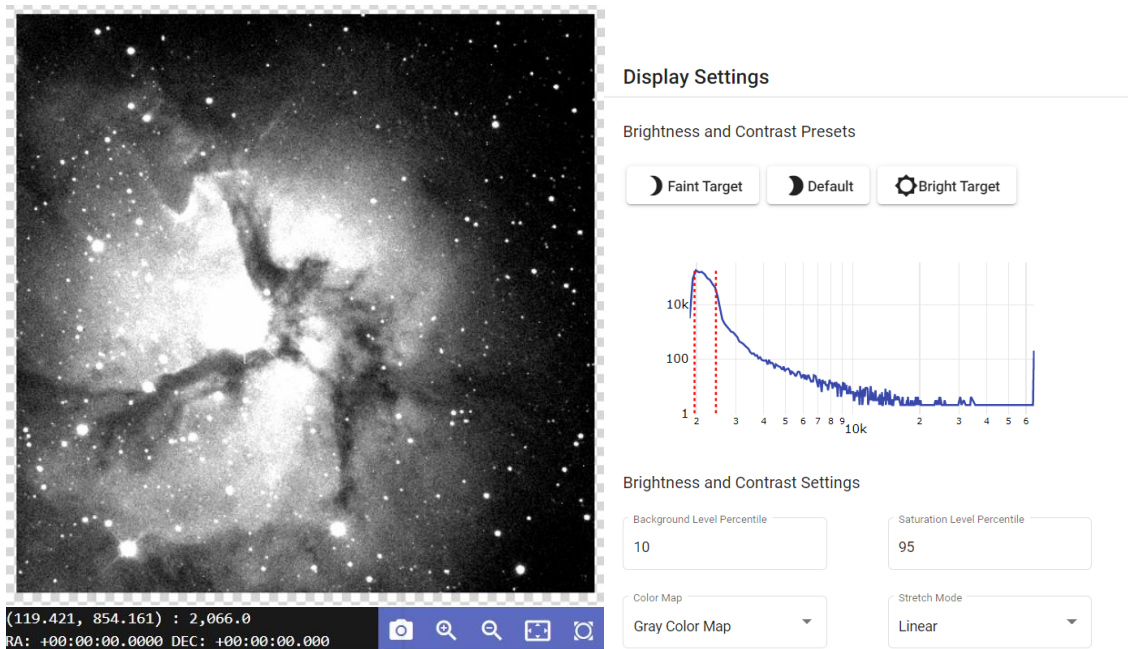
## Comparing Brightness Presets On Your Own

Below are the images of Kleopatra and the Trifid Nebula in their assigned preset. Now, try comparing them on your own. Open the Kleopatra\_1.fits file. Compare the image to the image of Kleopatra in its assigned preset below. Now, toggle between the different Brightness and Contrast presets.



**Caption:** Shown above is the asteroid Kleopatra image in its assigned **Bright Target** preset. The left-hand portion of the image has an image of Kleopatra. The image does not show the background noise. Rather, it only contains the asteroid and one star. The right half of the image has a histogram. The x-axis represents the brightness, or intensity, of the pixels. The y-axis represents the number of pixels at the given brightness.

After comparing the Kleopatra images in each of the presets, open the Trifid Nebula.fits file. Compare the image to the image of the Trifid Nebula in its assigned preset below. Now, toggle between the different Brightness and Contrast presets.



**Caption:** Shown above is the Trifid Nebula in its assigned **Faint Target** preset. The left-hand portion of the image contains the image of the Trifid Nebula. The Trifid Nebula is bright in the center, and it contains gas structures that branch out from the center of the image. The right half of the image has a histogram. The x-axis represents the brightness, or intensity, of the pixels. The y-axis represents the number of pixels at the given brightness.

## 15-b

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### Sonification: Going Deeper

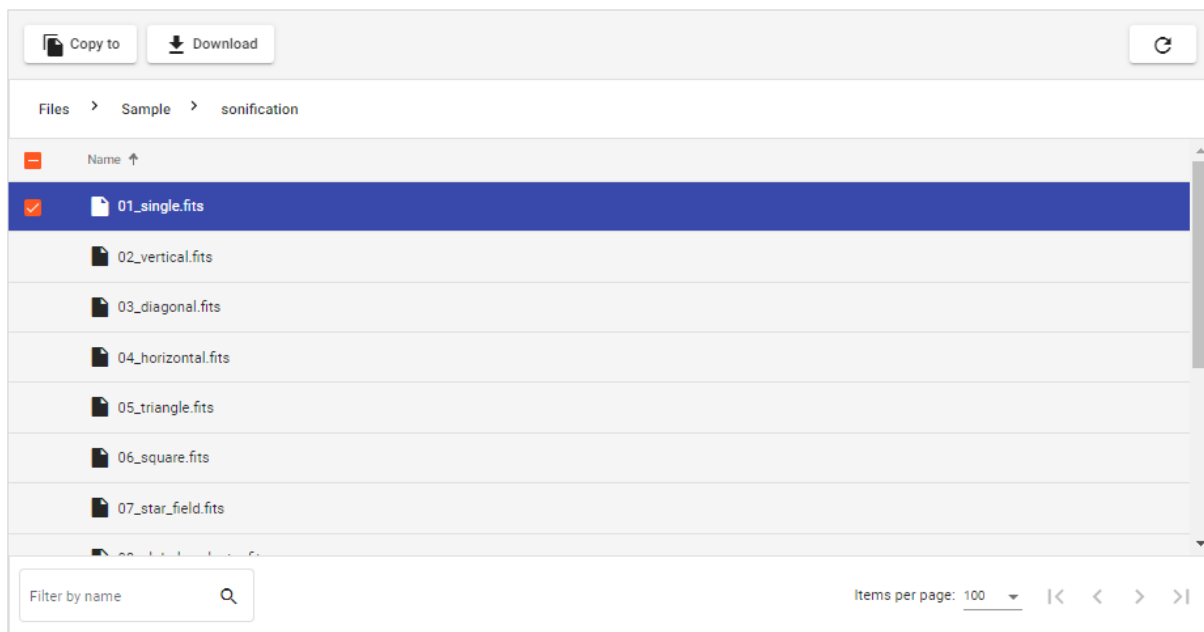
This activity will show you how the Sonification tool works. Ultimately, the purpose of this Going Deeper activity is to train your ear to recognize and be able to properly utilize the Sonification tool.

#### Sonifying an Image

First, open the “01\_single.fits” file.

1. Click on the **Open Files** button.
2. Select the Sample folder.
3. Select the Sonification folder.
4. Select the “01\_single.fits” file.

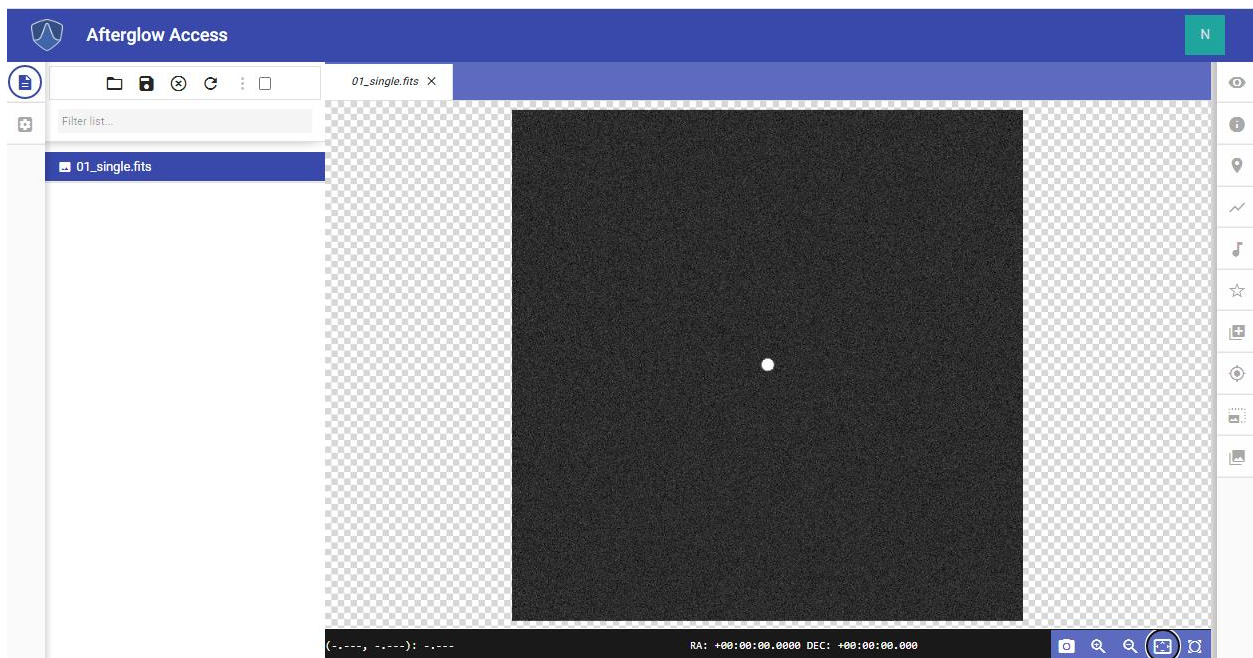
Open File



Open Cancel

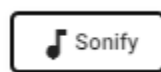
**Caption:** Above is the window that is shown when looking at the partial list of files in the Sonification folder. The Sonification folder is found in the Sample folder.

Once this file is in the file library list, open the image. Then, select the **Zoom to Fit** button.



**Caption:** A picture of the night sky that contains a single bright star/dot is shown in the entire AgA window. The file library list is open on the left side of the image.

Then, select the Show Sonification tab on the right side of the AgA window. Once the Sonification tool panel is open, select the **Sonify** button at the bottom of the tool panel.



A blue horizontal sonification line will now move up the image. A starting tone will begin the sonification, and a quiet range of tones will be heard as the line moves up. At the midpoint, when it crosses over the bright star, there will be a loud mid-range tone. Then, the quiet range of tones will be heard as the line moves to the top. An ending tone will then indicate when it reaches the end of the image.

### ***Duration and Tones***

The default sonification duration is 10 seconds, and the default number of tones is 22 tones. Change the value in the Duration value box to 5 and the value in the Tones value box to 5. This will cause the sonification to occur in 5 seconds with a total of 5 different tones. Then, click on the **Sonify** button to listen to the difference.

#### **Sonifier**

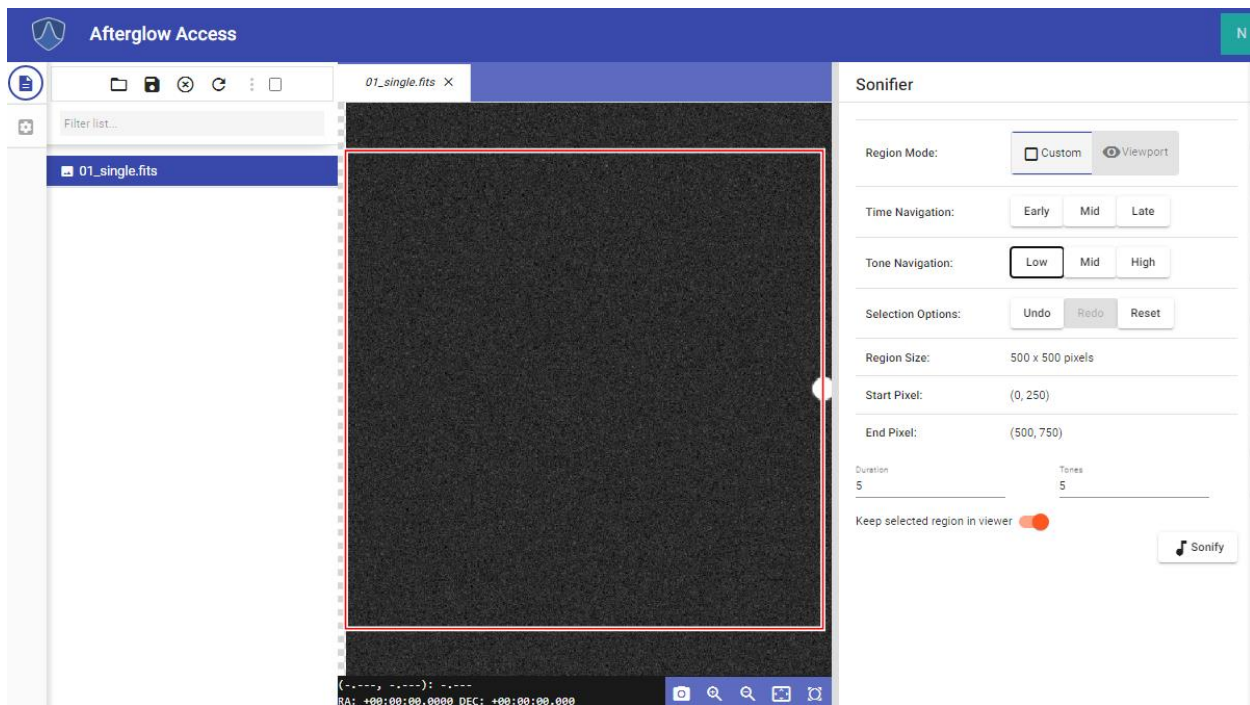
Region Mode:	<input type="checkbox"/> Custom	<input checked="" type="radio"/> Viewport
Region Size:	760.35 x 563.6 pixels	
Start Pixel:	(0.5, 240.15)	
End Pixel:	(564.1, 1,000.5)	
Duration	Tones	
5	5	
Keep selected region in viewer <input checked="" type="checkbox"/>		
<div>Sonify</div>		

**Caption:** The Sonification tool panel is shown when the Duration is changed to 5 seconds and there are only 5 tones.

### ***Custom Region Mode***

Select the **Custom Region Mode** button at the top of the Sonification tool panel. Now, select the **Mid** Time Navigation button. Then, select the **Low** Tone Navigation button. Finally, click on the **Sonify** button.





**Caption:** A picture of the night sky that contains a single bright star/dot in the far right is shown in the entire AgA window. The file library list is open on the left-hand side of the image. The Sonification tool panel is shown with the Custom Region Mode settings.

After listening to the difference, select the **Undo** button. Then, select the **High Tone** Navigation button. Finally, click on the **Sonify** button.

The star is located in a different location of the sonified region, which causes the tone to be different. As you continue to click on the Time Navigation and Tone Navigation buttons, the region that will be sonified will continue to be narrowed down.

## Training Your Ear

In the Sonification folder, there are 13 additional images that are beneficial to explore and will help you train your ear.

The second, third, fourth, fifth, and sixth images are similar to the image that was used above, except they have additional stars that are located in different arrangements.

Image “13\_asteroid.fits” is a series of images that have been stacked to show an asteroid moving across the sky.



For even more images, navigate to the Shapes folder, which is located in the IDATA folder. The IDATA folder is located in the Sample folder. The Shapes folder contains images of four different shapes that can also be used to train your ear to sonification.

## 15-c

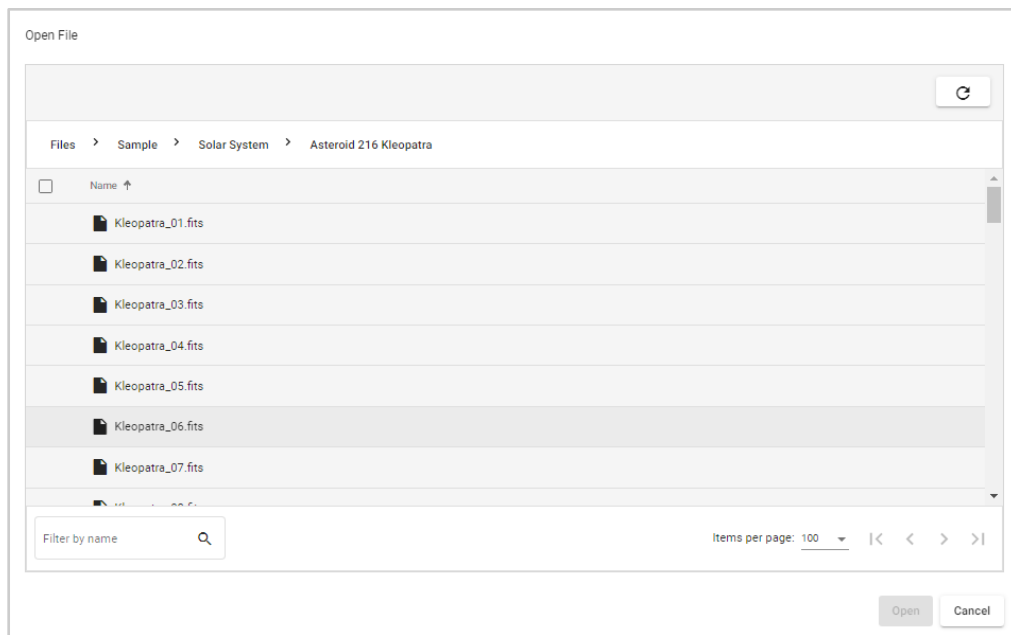
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### Aligner: Going Deeper

This is the first activity in a group of three Going Deeper activities that will utilize the Aligner, Stacker, and Custom Markers tools. The activities will be divided according to these sections. Together, these activities will answer the question, “How can astronomers discover or find asteroids?”

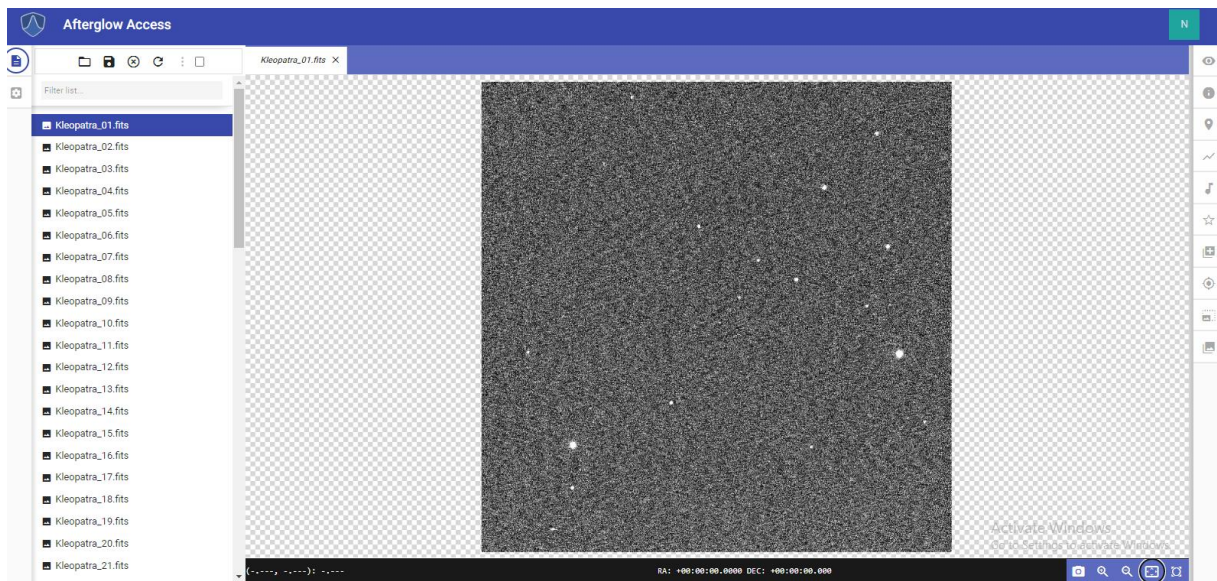
This activity will utilize the entire Kleopatra data set. In order to open the data set, follow the instructions below.

1. Select the **Open Files** button.
2. Select the Sample folder.
3. Select the Solar System folder.
4. Select the Asteroid 216 Kleopatra folder. There should be 68 images in the folder.
5. Select all of the images by clicking on the box to the left of “Name”. It is located near the top left of the folder directory pop-up window.
6. Click on the **Open** button.



**Caption:** Above is the window that is shown when looking at the partial list of Kleopatra files in the Asteroid 216 Kleopatra folder. This folder is found in the Solar System folder, which is in turn found in the Sample folder.

Once all of the files are in the file library list, click on the Kleopatra\_01.fits file. Select the **Zoom to Fit** button.



**Caption:** A picture of the night sky that contains the asteroid 216 Kleopatra is shown in the entire AgA window. The file library list is open on the left side of the image. The image of the night sky is located in the center, and it has several bright dots that appear like stars. One of these dots is Kleopatra.

Now, repeat the same steps with Kleopatra\_02.fits and Kleopatra\_13.fits. Then, toggle between these three images. It becomes apparent that several of the white dots are either not exactly lined up or are not in the same orientation. This is due to the fact that the telescope is not pointed at the exact same point for all of the images or that the images are rotated in a different direction.

Now, select the Show Aligner tab on the right. If the Kleopatra images are the only files in your file library list, click on the outlined box to the right of the **“Select Image(s) to Align”** drop-down menu. This button selects all of the images in the file library list. Next, select Kleopatra\_01.fits for the file in the **“Reference Image File”** drop-down menu. Finally, click on the **Submit** button.

Now, all 68 images are aligned. This ensures that the background stars in the images will line up perfectly, which will allow the images to be stacked successfully.

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### Stacker: Going Deeper

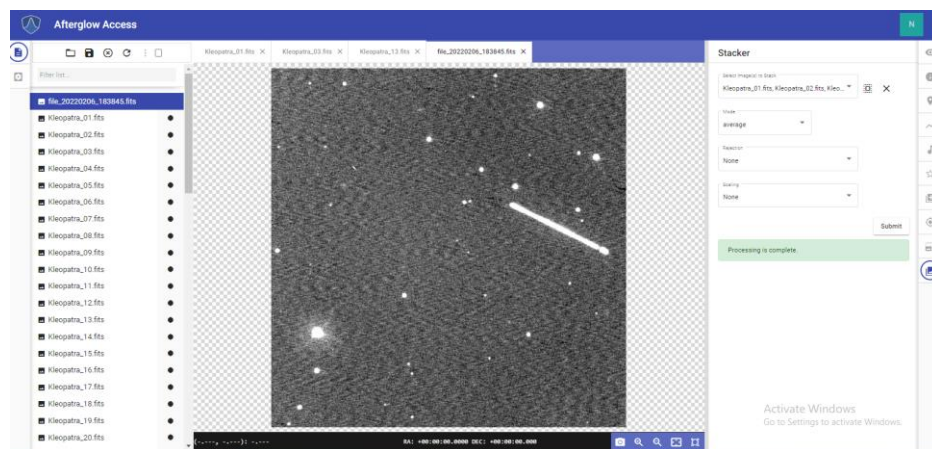
This is the second activity in a group of three Going Deeper activities that utilize the Aligner, Stacker, and Custom Markers tools. The activities are divided according to these sections. Together, these activities will answer the question, “How can astronomers discover or find asteroids?”

Note: If you have not completed the Aligner Going Deeper section, go to that section and complete it now.

Now that all of the Kleopatra images have been aligned, select the Show Stacker tab on the AgA toolbar. Then, if there are only Kleopatra images in the file library list, click on the outlined box next to the “**Select Image(s) to Stack**” drop-down menu. This selects all of the images in the file library list. Then, click on the **Submit** button.

A new file should appear in the file library list. It should be at the top of the list, and it should start with the word “file” instead of Kleopatra. Go to the file library list, and open this file.

Now, select the **Zoom to Fit** button.



**Caption:** The stacked image of the Kleopatra files is shown in the entire AgA window. The file library list is open on the left side of the image. The Stacker tool panel is open on the right side of the image. The stacked image is located in the center and features several bright dots (stars) throughout the image. Moreover, near the top right of the image is a diagonal line of light, which is all of the stacked Kleopatra images.

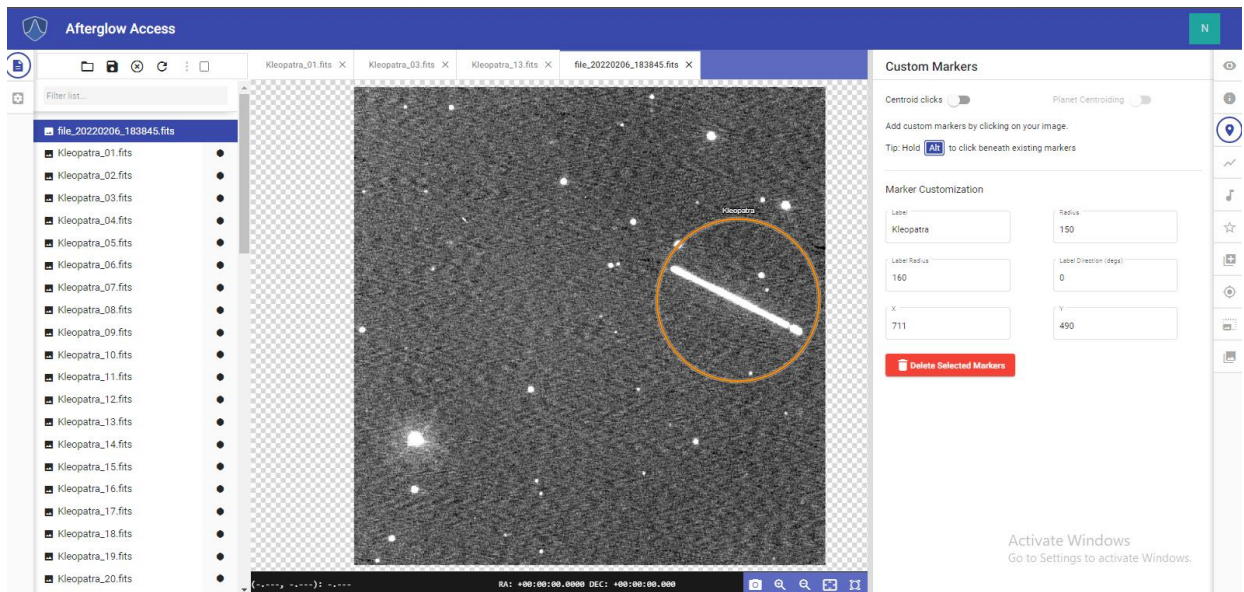
## Custom Markers: Going Deeper

This is the third activity in a group of three Going Deeper activities that utilize the Aligner, Stacker, and Custom Markers tools. The activities are divided according to these sections. Together, these activities will answer the question, “How can astronomers discover or find asteroids?”

Note: If you have not completed the Aligner and/or Stacker Going Deeper sections, go to those activities and complete them now.

Follow the steps to put a custom marker around the diagonal line of Kleopatra images.

1. Select the Show Custom Markers tab on the right.
2. Click on the image in the middle of the Kleopatra “line” which will add a small circle. Double click on the circle which will turn it orange and will show you the Marker Customization settings.
3. Type “Kleopatra” in the Label box.
4. Change the value in the Radius value box, so the entire line is in the circle.
5. Change the value in the Label Radius value box so the label Kleopatra is just outside the circle.
6. Experiment with changing the position of the Label by changing the value in the Label Direction box.
7. Experiment with changing the values in the X box and the Y box. Changing the X value will move the marker side to side and changing the Y value will move the marker up and down.

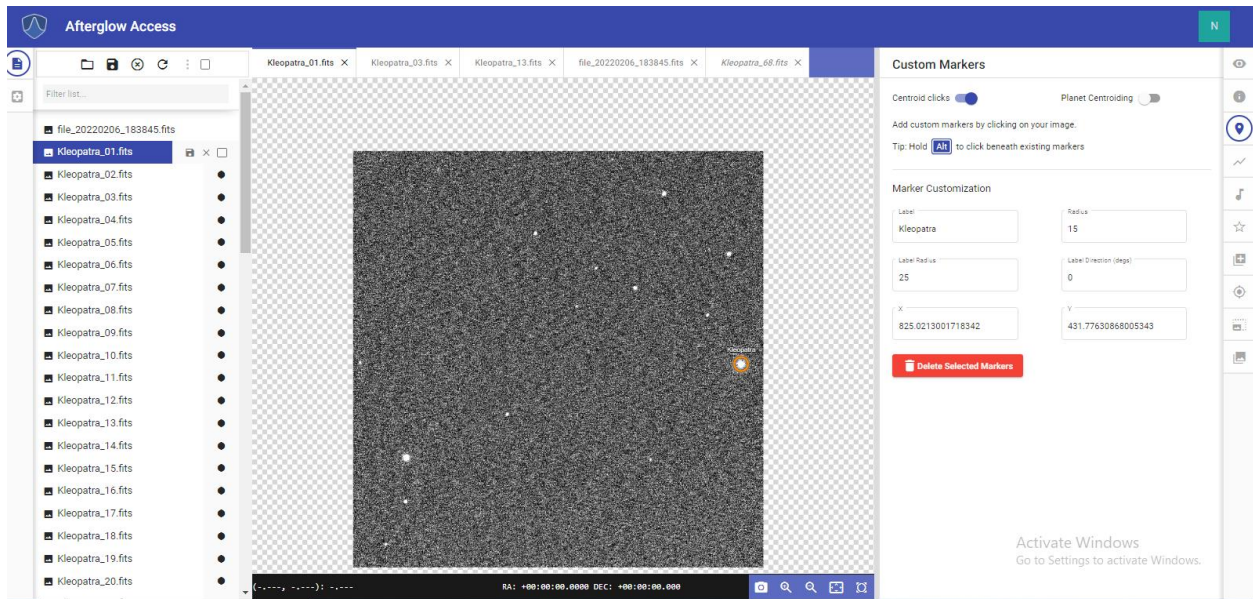


**Caption:** The stacked image of the Kleopatra files is shown in the entire AgA window. The file library list is open on the left side of the image. The Stacker tool panel is open on the right side of the image. The stacked image is located in the center and features several bright dots throughout the image. Moreover, near the top right of the image is a diagonal line of light, which is all of the stacked Kleopatra images. Around this diagonal line is an orange circular outline. This is a custom marker. Above this circle is the label “Kleopatra”.

Now, follow the steps to put a custom marker around a single image of Kleopatra.

1. Select Kleopatra\_01.fits in the file library list.
2. Turn on the “**Centroid Clicks**” toggle button.
3. Find the dot that is Kleopatra in the image, and click near the dot. A small circle should now surround Kleopatra.
4. Double click on the circle. This will turn the marker orange, and the Marker Customization settings will become visible in the Custom Markers tool panel.
5. Type “Kleopatra” in the Label box.
6. Change the value of the Radius box so that the circle is larger than Kleopatra.
7. Change the value in the Label Radius box so that the label Kleopatra is just outside the circle.





**Caption:** A picture of the night sky that contains the asteroid 216 Kleopatra is shown in the entire AgA window. The file library list is open on the left side of the image. The image of the night sky is located in the center, and it has several bright dots that appear like stars. One of these dots is Kleopatra. Around Kleopatra is an orange circular outline. This is a custom marker. Above the custom marker is the label “Kleopatra”.

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### Plotter: Going Deeper

This is the first activity in a group of two Going Deeper activities that will utilize the Aligner, Stacker, File Info, Plotter, and Photometry tools. The activities will be divided according to the Plotter and Photometry sections. Together, these activities will answer the question, “How can astronomers determine the rotation rate of asteroids?”

Note: These sections will utilize the Aligner and Stacker tools. This section should only be completed after the user has completed the Aligner and Stacker Going Deeper activities, which explored the question, “How can astronomers discover or find asteroids?”

This activity will utilize part of the Kleopatra data set. In order to open the data set, follow the instructions below.

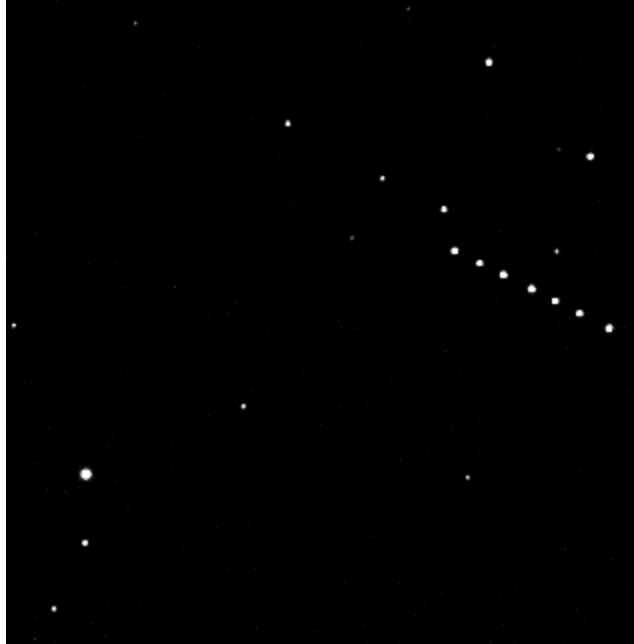
1. Select the **Open Files** button.
2. Select the Sample folder.
3. Select the Solar System folder.
4. Select the Asteroid 216 Kleopatra folder. There should be 68 images in the folder.
5. Select the files Kleopatra\_01.fits, Kleopatra\_11.fits, Kleopatra\_21.fits, Kleopatra\_31.fits, Kleopatra\_41.fits, Kleopatra\_51.fits, and Kleopatra\_61.fits.
6. Click on the **Open** button.

Now, utilizing the directions found in the Aligner Going Deeper section, align this data set (referenced to Kleopatra\_01.fits). If you need additional help, visit the Aligner section of this manual. After you have successfully aligned the images, stack the data set. If you need additional help with this step, visit either the Stacker section of this manual or the Stacker Going Deeper section.

Reference the image below to ensure that these steps were completed successfully.

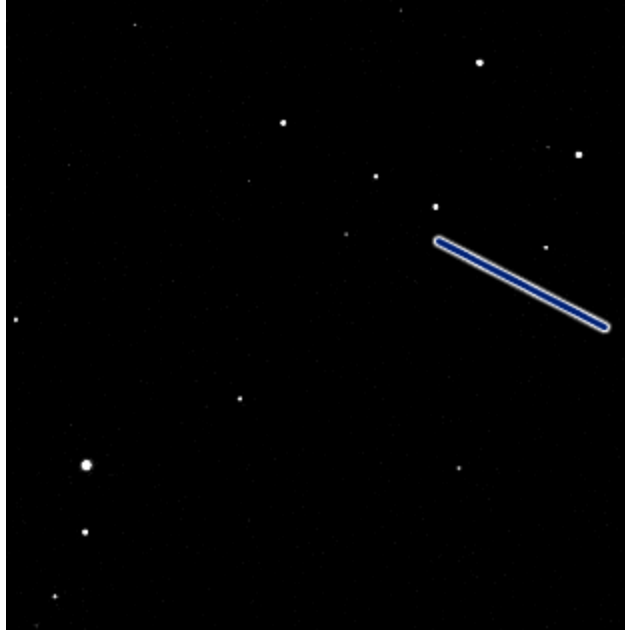
Note: In the Display Settings tool, the background level percentile was set to 89.2% and the saturation level percentile was set to 99.9%.





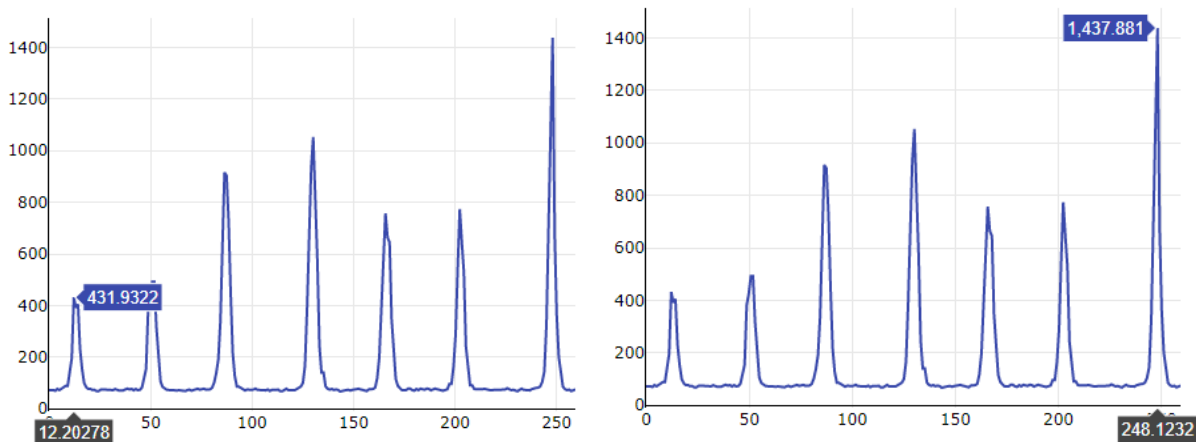
**Caption:** The stacked image of the Kleopatra files is shown above. There are several stars located throughout the image. Moreover, near the top right of the image is a diagonal line of dots. Each dot is asteroid Kleopatra, and the line of dots represents the movement of Kleopatra.

Now, open the Plotter tool. The Plotter tool can be used to measure how far an asteroid has moved from one image to another image. Select a point that is in line with the diagonal line of the Kleopatra images. Then select a second point such that the line passes through all of the points where Kleopatra is. A reference image with an appropriate line is shown below.



**Caption:** The stacked image of the Kleopatra files is shown above. The image has several stars throughout it. Moreover, near the top right of the image is a diagonal line that covers all of the Kleopatra images.

Now, there should be an x-y plot in the Plotter tool that has seven peaks. The x-axis location of each peak represents the pixel location of Kleopatra along the selected line. By looking at the pixel position of each point where Kleopatra is located, you can start to understand how fast Kleopatra is moving across the field of view. Hover your mouse over two peaks in the graph to find the pixel position of two of the Kleopatra images.



**Caption:** The x-y plot of the cross section including the Kleopatra images is shown above twice. Each time, the x-y plot has seven peaks. The x-axis represents the pixel location across the line and the y-axis represents the intensity of each pixel on the line. The x- and y-values for the center of the first peak are shown in the left image. The x- and y-values are (12.20278, 431.9322). The x- and y-values for the center of the last peak are shown in the right image. The x- and y-values are (248.1232, 1437.881).

The position of Kleopatra in the first image is 12.20278 and in the last image it is 248.1232. This imputes a total distance traveled of 235.92042 pixels. In order to see how fast Kleopatra is traveling, look at the center time value for each image in the File Info tool. Since this is for the first image and the last image, obtain this value for Kleopatra\_01.fits and Kleopatra\_61.fits.

Center Time	2008-11-11 23:56:12 GMT+0
Center Time	2008-11-12 04:35:01 GMT+0

Kleopatra\_01.fits was taken on November 11, 2008 at 11:56:12 pm. Kleopatra\_61.fits was taken on November 12, 2008 at 4:35:01 am. Therefore, a total of 16,729 seconds passed between the images. Now, divide the number of pixels between the two images (235.92042) by the amount of time that passed between the two images (16,729 seconds). This yields a speed of roughly 0.014 pixels/second.

## 15-g

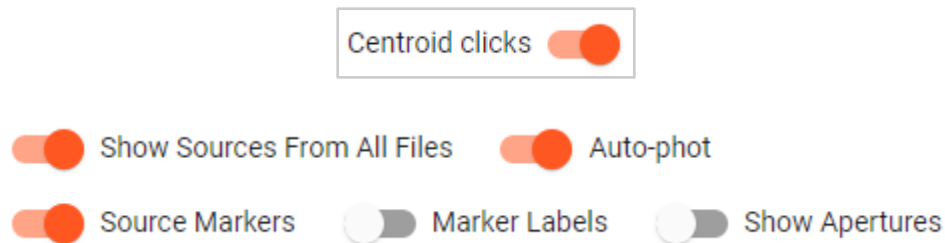
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### Photometry: Going Deeper

This is the second activity in a group of two Going Deeper activities that will utilize the Aligner, Stacker, File Info, Plotter, and Photometry tools. The activities will be divided according to the Plotter and Photometry sections. Together, these activities will answer the question, “How can astronomers determine the rotation rate of asteroids?”

Note: If you have not completed the Plotter Going Deeper section, go to that activity and complete it now.

Since you have completed the Plotter Going Deeper activity, you should have a stacked image of seven Kleopatra images. Once that image is open in the display window, open the Photometry tool. Ensure that the **“Centroid clicks”**, **“Show Sources From All Files”**, **“Auto-phot”**, and **“Source Markers”** toggle buttons are all toggled on.



Note: Toggling on the “Show Apertures” toggle button may help you see exactly where you selected a source.

Now, select each point in the stacked image where Kleopatra appears. The first Kleopatra image that you should click is the lower right dot on the diagonal line. Then, work your way up through the line. The last image of Kleopatra that you should click is the top left dot. There should be a total of seven sources selected. Now that you have selected each of your sources, the magnitude of each point will be given in the table in the Photometry tool.



**Caption:** The stacked image of the Kleopatra files is shown above. There are several stars located throughout the image. Moreover, near the top right of the image is a diagonal line of dots. Each dot is asteroid Kleopatra, and the line of dots represents the movement of Kleopatra. Each of these dots is numbered either 1-7. The dot on the lower right is numbered 1, and the dot on the upper left is labeled 7. This represents the order that the dots should be clicked.

<input type="checkbox"/>	Label	X   RA	Y   DEC	Mag	Mag Err
<input type="checkbox"/>	0	+23:01:25.21	+02:04:44.498	12.307	0.011
<input type="checkbox"/>	1	+23:01:26.773	+02:04:32.116	12.803	0.016
<input type="checkbox"/>	2	+23:01:28.023	+02:04:22.263	12.922	0.018
<input type="checkbox"/>	3	+23:01:29.28	+02:04:12.434	12.382	0.012
<input type="checkbox"/>	4	+23:01:30.768	+02:04:0.818	12.532	0.013
<input type="checkbox"/>	5	+23:01:32.032	+02:03:51.171	13.249	0.023
<input type="checkbox"/>	6	+23:01:33.345	+02:03:41.269	12.806	0.016

**Caption:** The data for each of the Kleopatra images in the stacked image is shown above. The sources are labeled 0-6, and the RA, DEC, magnitude, and magnitude error are given for each source.

Now, look at the magnitude of each point in the table. It changes with time. This suggests that the asteroid is not the same brightness over its entire surface and that it is rotating. You can estimate the rotation rate by looking at the time when the images were taken, the magnitude estimated at that time, and at the peaks or troughs in the light curve. Through all of this information, you can begin to understand the rotation rate of the asteroid.

In the images that were used, the images labeled 0 and 3 seem to be the brightest. This indicates that the brightest part of the asteroid is facing you. Source 0 has a magnitude of 12.307 and source 3 has a magnitude of 12.382.

Note: Brighter sources have a smaller magnitude.

	Label	X   RA	Y   DEC	Mag	Mag Err
<input checked="" type="checkbox"/>	0	+23:01:25.21	+02:04:44.498	12.307	0.011
<input type="checkbox"/>	1	+23:01:26.773	+02:04:32.116	12.803	0.016
<input type="checkbox"/>	2	+23:01:28.023	+02:04:22.263	12.922	0.018
<input checked="" type="checkbox"/>	3	+23:01:29.28	+02:04:12.434	12.382	0.012
<input type="checkbox"/>	4	+23:01:30.768	+02:04:0.818	12.532	0.013
<input type="checkbox"/>	5	+23:01:32.032	+02:03:51.171	13.249	0.023
<input type="checkbox"/>	6	+23:01:33.345	+02:03:41.269	12.806	0.016

**Caption:** The data for each of the Kleopatra images in the stacked image is shown above. The sources are labeled 0-6, and the RA, DEC, magnitude, and magnitude error are given for each source. Source 0 and source 3 are selected.

Now, using the File Info tool, find the time when source 0 and source 3 were taken. Kleopatra\_01.fits (labeled 0 in the source list) was taken on November 11, 2008 at 11:56:12 pm.

 2008-11-11 23:56:12 GMT+0

Kleopatra\_31.fits (labeled 3 in the source list) was taken on November 12, 2008 at 2:17:07 am.

 2008-11-12 02:17:07 GMT+0

This means that the rotation rate of Kleopatra should be roughly 2 hours and 21 minutes since this is the time between two peaks in brightness. However, if you check the rotation rate of asteroid 216 Kleopatra online, this is not the rotation rate. The rotation rate of Kleopatra is approximately 5 hours, 23 minutes, and 24 seconds. You may be wondering why there is this discrepancy. However, if you look at the entire Kleopatra data set, the time from when Kleopatra\_01.fits was taken to when Kleopatra\_68.fits was taken is roughly 5 hours and 8 minutes. Therefore, the entire data set was taken in a shorter amount of time than the rotation rate of Kleopatra. If the data set was taken in a longer amount of time, then you could use this same method to find the actual rotation rate. The only reason that it appeared like we could find the rotation rate was because Kleopatra's brightness varies in a way that there is more than one area on the asteroid that reflects the peak brightness.

## 15-h

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### Pixel Operations: Going Deeper

This Going Deeper activity will use the “Add +” operand found in the Pixel Operations tool to modify an image of Saturn and Jupiter. The resulting image will be further fine-tuned using the Display Settings tool.

#### The Needed Files

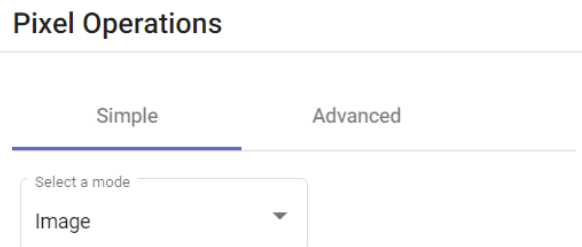
First, open the saturn.fits file:

1. Click on the **Open Files** button.
2. Select the Sample folder.
3. Select the Solar System folder.
4. Select the saturn.fits file.

Next, open the jupiter.fits file:

1. Click on the **Open Files** button.
2. Select the Sample folder.
3. Select the Solar System folder.
4. Select the jupiter.fits file.

These files should now be in the file library list. Open the saturn.fits file, and ensure that it is displayed in the AgA window. Then, click on the Show Pixel Operations tab on the AgA toolbar. Ensure that you are using the Simple settings, and that Image is the selected mode.



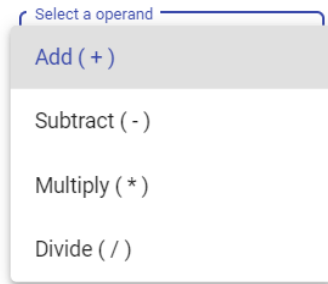
Since the image of Saturn is open in the display window, the saturn.fits file should be in the “**Selected Image(s)**” drop-down menu.





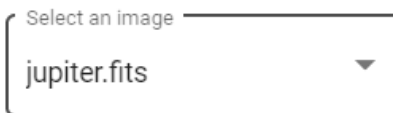
Selected Image(s)  
saturn.fits

Next, select the “Add +” operand from the “**Select an operand**” drop-down menu. This selection dictates what operation will be performed between the images of Saturn and Jupiter.



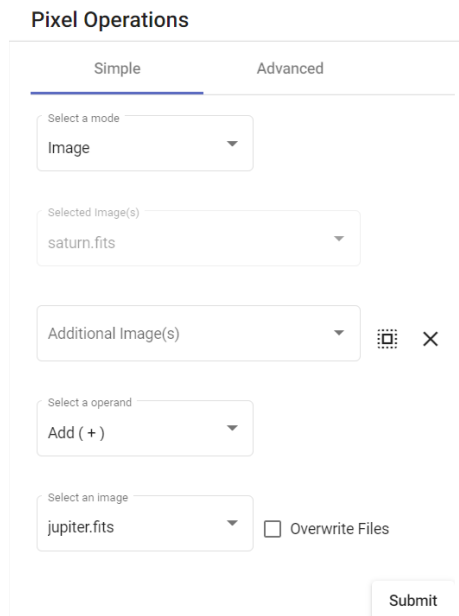
Select an operand  
Add ( + )  
Subtract ( - )  
Multiply ( \* )  
Divide ( / )

Now, select jupiter.fits in the “**Select an Image**” drop-down menu. This ensures that the image of Jupiter will be added to the image of Saturn.



Select an image  
jupiter.fits

Before clicking on the **Submit** button, compare your settings to the screenshot below. This screenshot shows what each of the selections should be.





Pixel Operations

Simple Advanced

Select a mode  
Image

Selected Image(s)  
saturn.fits

Additional Image(s)  

Select an operand  
Add ( + )

Select an image  
jupiter.fits

☐ Overwrite Files

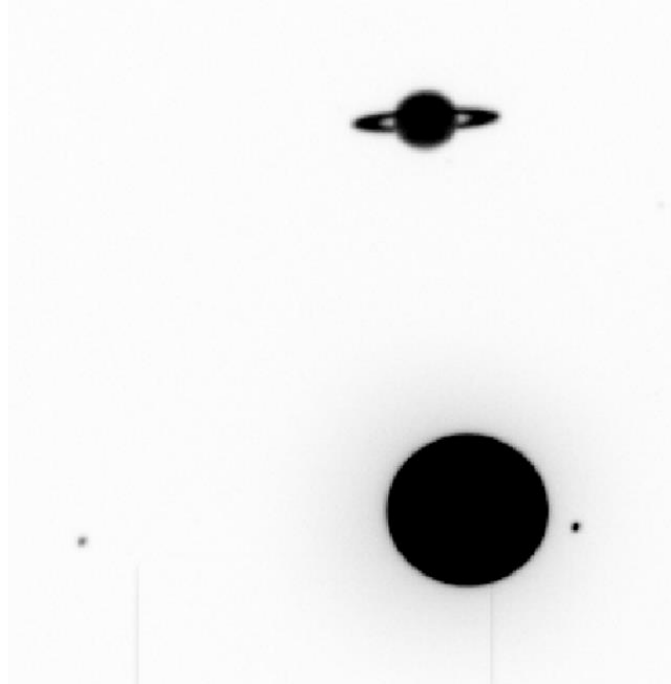
Submit

After this comparison, click on the **Submit** button. Since the **Overwrite Files** button was not selected, it should create a new file in the file library list. Open this file.



**Caption:** A new image was created as a result of the application of the pixel operand performed on the Jupiter and Saturn images, and it is shown above. The image shows Saturn, Jupiter, and three of Jupiter's moons.

Now, click on the Show Display Settings tab on the AgA toolbar. Manipulating these settings allows the user to finetune the image's features. The first suggested change is changing the Saturation Level Percentile to 99.5. The second suggested change is inverting the image by clicking on the **"Inverted"** toggle button. However, you are encouraged to explore the different ways that this image can be displayed.



**Caption:** A new image was created as a result of the application of the pixel operand performed on the Jupiter and Saturn images, and it is shown above. The image shows Saturn, Jupiter, and some of Jupiter's moons. The image is shown using a gray color map. It is also inverted and zoomed in. Both planets are visible, as are two of Jupiter's moons.

## GLOSSARY

**Afterglow Access (AgA):** A complete browser-based astronomy image and data analysis software tool. The software is designed to work with screen readers and incorporates unique features that allow the user to experience images through sound. This makes astronomy more accessible to the blind and visually impaired.

**Arcminutes:** An angle measurement used in locating the position and size of astronomical objects. There are 60 arcminutes in a degree. Most astronomical objects appear much smaller than a degree in the sky, so arcminutes are more useful for measuring their size. The full moon is 30 arcminutes in the sky.

**Arcseconds:** An angle measurement used in locating the position and size of astronomical objects. There are 60 arcseconds in an arcminute, and 3600 arcseconds in a degree.

**Autoscale:** Automatically scaling an image

**Batch Data:** Multiple pieces of data

**Blind and Visually Impaired (BVI):** Any person who has a corrected visual acuity of less than either 20/40 or 20/60

**Centroid Click:** The use of an algorithm that shifts a marker to the point of the peak value, instead of the exact pixel clicked

**Color Palette:** A group of colors

**Composite Image:** An image made up of multiple images

**Contrast:** The degree of difference between the tones in an image

**Cross-section:** A graphic representation of the pixel intensity along a selected line segment

**Declination:** The name astronomers give to imaginary lines on the night sky similar to the lines of latitude on Earth. It is measured in degrees, minutes, and seconds.

**.fits:** An open standard defining a digital file format useful for the storage, transmission, and processing of data

**Histogram:** A graphical representation of data. Data are grouped into corresponding bins of intensity values on the x-axis. The y-axis then counts the number of pixels that fall into each brightness bin.

**Intensity:** Level of brightness in a pixel

**Inverting:** Flipping the colors in an image; e.g. black becomes white and white becomes black

**.jpeg:** A common file format used in digital photography, in which the photo is compressed but loses some of its quality. JPEG stands for “Joint Photographic Experts Group”

**Kernel Filter:** A filter applied to images for blurring, sharpening, and more. This is accomplished by taking a matrix, usually 3x3, and completing a specified mathematical function to each pixel in the matrix. The resulting value of this function is then applied to the pixel in the center of the matrix.

**Normalization:** A process through which pixels are assigned a color. The key parts of normalization are determining which pixel values are the darkest color, which pixel values are the lightest color, and how to assign the interim colors.

**Orientation:** The layout of the image, which is impacted by transformations. Examples of transformations include flipping, mirroring, and rotating.

**Pixel:** Smallest unit in a digital image

**Planet Centroiding:** The use of an algorithm that shifts a marker to the center of a planet, instead of the exact pixel clicked. It differs from regular centroiding because the algorithm is different since planets are not point sources.

**Point Source:** A localized point of light, such as a star

**Radius:** The length from the center of a custom marker circle to the outline of the marker, measured in pixels

**Right Ascension:** The name astronomers give to imaginary lines on the night sky similar to the lines of longitude on Earth. These lines run from pole to pole through the celestial equator. It is measured in hours, minutes, and seconds.

**Saturation Level Percentile:** A value that is related to the intensity assigned to the color white, or the lightest color in a colormap

**Sonification:** The use of sound to represent data that is typically presented visually

**Toggle Button:** A switch to turn functions on and off in AgA

**Workbench Panel:** The sections of AgA that either contain the tools or display the image

**World Coordinate System (WCS):** This system maps each pixel in an image to specific right ascension and declination coordinates in the night sky

**x-y plot:** A graphical display of data that shows one set of information on the x-axis and another set of information on the y-axis

## APPENDIX

### Shortcut Keys

The plus sign, “+,” is used to signify that two keys need to be pressed, not that you need to press the plus sign. While in some cases, the order in which the keys are pressed does not matter, sometimes the order does matter.

#### *Workbench Shortcuts*

Key	Description
shift + T	Open Theme Settings
?	Open Help Dialog
shift + F	Open File Manager
d	Display Tool
i	File Info Tool
m	Custom Markers Tool
shift + P	Plotting Tool
s	Sonification Tool
p	Photometry Tool
*	Pixel Operations
w	WCS Calibration Tool

a	Aligning Tool
shift + S	Stacking Tool
esc	Exit Expanded Panel View
,	Expand Workbench File Panel
.	Expand Workbench Image Panel
/	Expand Workbench Tool Panel



## ***Sonification Shortcuts***

<b>Key</b>	<b>Description</b>
space	Play Sonification
ctrl + z	Undo Region Change
ctrl + y	Redo Region Change
left arrow	Navigation: Low Frequency
right arrow	Navigation: High Frequency
left arrow + right arrow	Navigation: Mid Frequency
down arrow	Navigation: Early
up arrow	Navigation: Late
down arrow + up arrow	Navigation: Middle
1	Navigation: Low Frequency   Beginning
2	Navigation: Mid Frequency   Beginning
3	Navigation: High Frequency   Beginning
4	Navigation: Low Frequency   Middle
5	Navigation: Mid Frequency   Middle
6	Navigation: High Frequency   Middle
7	Navigation: Low Frequency   End
8	Navigation: Mid Frequency   End
9	Navigation: High Frequency   End
0	Reset Sonification Region

### ***Image Viewer Shortcuts***

<b>Key</b>	<b>Description</b>
=	Zoom in
-	Zoom out
r	Reset zoom
z	Zoom to fit

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