Remote Astrophotography Using Slooh.com

A Handbook

Fourth Edition

May 2024

Erik Westermann

This book is dedicated to my mother, Ursula Westermann

Thank you for everything you do

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Table of Contents

Introduction

My name is Erik Westermann, and I have been observing the skies since I was in my early teens. I was always fascinated with the night sky, the movement of the moon, the patterns the stars made in the sky and was always curious about the sky.

Due to life and other circumstances, I essentially gave up on actively participating in astronomy. However, years later, when I restarted my hobby, I was both impressed and overwhelmed at the amount of information that was available. I learned that there are a lot of things to know to become a good astrophotographer yet there was not a single source of information that targeted someone new both to astronomy and new remote imaging using Slooh. I thought of all of the pain points I came across and how I ultimately overcame them. Sometimes solutions were easy, other times the solution was buried in layers of knowledge. I thought of writing blog posts about my findings, yet blog posts are meant to be short and concise and what I wanted to say wasn't going to work in that format. So the next best thing was to compile everything I learned into one easy to use format: this is that book.

This is the fourth edition of the book and it's been updated to reflect the changes that Slooh released in 2023. There's lots of new content, some new chapters, and things have been rearranged to improve the overall flow.

I put several months of work into this book and am happy to share the result with you. Please subscribe to my newsletter on the companion website for updates to this book, as well as find out about any new books I may publish. The website is: http://RemoteAstrophotography.com

What's In This Book?

This book is a handbook for taking great photos of the skies based using Slooh.com, using Slooh to advance your knowledge of astronomy, and using Slooh to participate in an active online community. I cover how to use Slooh to acquire images of just about anything in the sky and also explain what you can do with those images. I describe in detail how to process your images to get the best result and explain a lot about astronomy and astrophotography along the way.

I explain the 'why' wherever possible while giving you practical advice.

I explain throughout the book what each section covers and next steps to take so you're never left alone. However, I also wanted to make this book a useful resource for reference, so each chapter can stand on its own.

This book spans three broad parts: Mission Planning and Booking, Viewing and Downloading Images, and Image Processing. There's a fourth part to the book in the Appendix where I discuss how I use Slooh, my adventures in exoplanet hunting and my history with astronomy and how I came across Slooh.

Of course, a book about astronomy would be incomplete if I didn't tell you about the tools and processes I used to write this book, so if you're interested, that's at the very end of the book.

What's New In The Fourth Edition

The fourth edition, May 2024 update, has lots of updates and new features:

- The Table of Contents is now linked, so you can simply click a section to jump to it right away
- References to other sections are now linked, so just click the underlined text to jump to the referenced section

The following was added in the fourth edition:

- Updated for the new Slooh Dashboard
- Details about using Slooh.com's JS9 FITS viewer to not only view images but also details about using it to create full color RGB images
- A new section on using Photopea, a free online image editor that's similar to Photoshop
- Updated section headings to make the text easier to read

Who Should Read This Book?

I have aimed this book at someone that's interested in astronomy at the beginner to intermediate level. You have an interest in the things you see in the sky at night but might not have a lot of background information and you want a place to start and have a good foundation to build upon.

If you're at the intermediate level, you'll also benefit from this book because I show you methods to improve your skills in composing your images, processing your images, and doing advanced things like photometry with your images.

I also intended this book to be for someone that's interested in expanding their knowledge based on practical advice and someone that has a willingness to experiment.

What You'll Need To Know

You're going to be spending a lot of time with your computer, so you need to be comfortable using it. I assume you're using a modern version of Windows.

You have to be comfortable with making folders, finding files, downloading things, installing software, and be comfortable enough to get yourself out of trouble. You should be relatively organized insofar as naming files and keeping them in different folders.

You should be comfortable using the internet, and a modern browser like Google's Chrome. You should also be comfortable using web-based applications where you have to sign-up or sign-in or enter detailed information on forms.

Learn More About Astronomy

This book teaches you how to observe the sky using Slooh.com. You can learn more about the things in the sky with my other free book, Introduction To The Cosmos.

Introduction To The Cosmos is for beginner to intermediate astronomers that want to learn more about the objects in the sky, including the lifetimes of stars, galaxies, nebulae, and much more.

Download your free copy of Introduction To the Cosmos here:

http://IntroductionToTheCosmos.com/

What You Need To Have

You need to have a membership to Slooh and have a suitable computer and internet connection. I discuss these things in this section.

Your Slooh Membership

Slooh offers a number of memberships to the public. For families, or for any small group, Slooh offers a master account with four sub accounts. For schools, Slooh offers a teacher account and student accounts. You can also get access to two other account types: Apprentice and Astronomer – you need to contact Slooh support to upgrade to these levels. The Apprentice and Astronomer accounts are individual accounts only and offer certain benefits that are also part of the family and teacher accounts. I explain membership levels in the section Understanding Slooh Membership Levels.

Your Computer

You'll need to be running a modern version of Microsoft Windows since I have you install and use software designed for it. You can certainly use Slooh without any of the software and this book covers those features as well. Your overall experience will be better with the software.

If you have a Mac, you can KStars but the directions will differ slightly as will how your screen appears. I used Windows versions of KStars to take the screenshots and develop the directions in this book.

You'll also have to have the ability to download and install software on your computer. Some systems restrict the rights you have on your own computer, so please make sure you can install software.

You'll require a stable and reasonably fast connection to the internet. Astronomy involves a fair bit of research, and you'll interact with Slooh online, so your connection has to be suitable for those purposes.

You'll ideally already have Google's Chrome browser installed. This is not a strict requirement; however, I used it during the writing of this book and the screenshots and functionality of Slooh may change slightly between browsers and platforms (for example, the Slooh.com website looks and behaves slightly differently on an iPad compared to how it operates on a PC running Chrome).

All of the software I have you install is available online and it is free, so there's no cost involved beyond the Slooh membership.

Understanding The Role Of The Companion Website - RemoteAstrophotography.com

The companion website at http://RemoteAstrophotography.com offers a lot of information that simply cannot fit in this book. I write a lot and often about Slooh, Image Processing, and publish my images that I capture using Slooh, the MicroObservatory and other services.

By visiting the website, you'll be right up to date on developments at Slooh and on developments related to image processing, since I can't update this book as often as I update the website. It's the best way to stay up to date between new editions of this book.

Visit http://RemoteAstrophotography.com today.

Conventions Used In This Book

Throughout the book, I'll ask you to type things or click on certain things. Where possible, I put the thing I want you to act on in quotes to separate them from the rest of the text.

Often, I ask you to type things and show them in quotes to make it easier to see. Sometimes things have embedded spaces, and the quotes help to offset those embedded spaces from the rest of the text. In those cases, just type what you see without the quotes.

I'll also often ask you to click things or select them. I write out the name of the thing I'd like you to select, like "File".

Sometimes you need to make a series of selections from menus. I write those out as steps without quotes, like this for opening a file: File - Open.

I include lots of screenshots to help you along the way. When I describe that you need to select something, check the location of my mouse pointer (or hand) in the screenshot to know where to click. In cases where things are close together or hard to spot, I highlight the area in yellow (of course, the yellow highlight won't be part of the screen you look at on your computer).

Quick Start

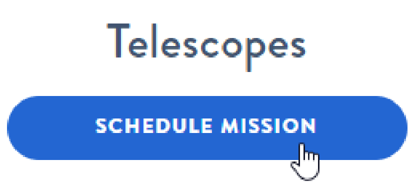
This section explains how to quickly get started using all of Slooh's features. I have references to other chapters in the book in case you want to learn more as we go along.

To make best use of this tutorial, you should be using Slooh from a computer or a device that allows you to use all of Slooh's features. Slooh's functionality changes based on your screen's size and I have noticed that there's limited functionality on a phone-sized screen; I have not tried Slooh on a tablet, like an iPad so your experience may vary if you use a device like that.

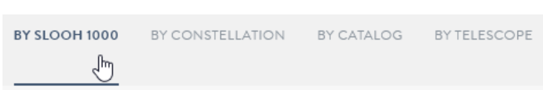
Taking Your First Image

We'll schedule a mission in this section after which you need to wait for Slooh to capture the image for you, so this tutorial might take a day for you to complete. I show you around Slooh while you wait for your image.

Start by logging into Slooh. Click the *Telescopes* icon at the top of the page and then click *Schedule Mission* as shown:

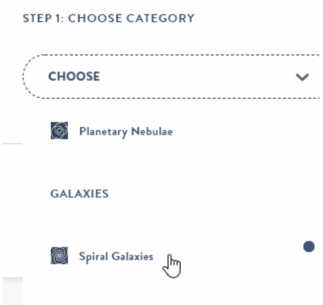


You can book missions in a variety of ways and the easiest is to use the Slooh 1000 List – a curated listing of 1000 interesting objects to image. Ensure that the "By Slooh 1000" tab is selected:

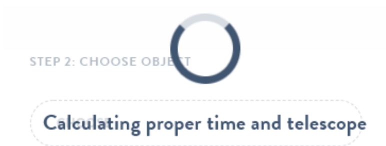


You can image a wide variety of objects including nebulae, galaxies, planets and more. I have you choose Spiral Galaxies here because they're usually relatively bright, resulting in nice images.

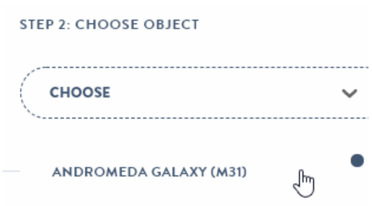
In "Step 1 – Choose Category", select "Spiral Galaxies" as shown:



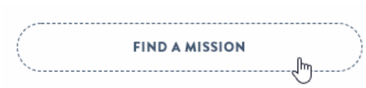
Slooh takes into consideration the type of object you want to image and what objects are visible today, so it runs some calculations that can take a while to complete:



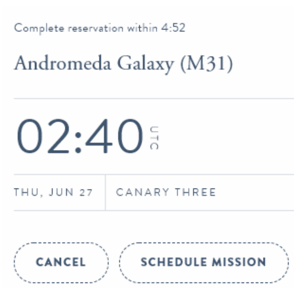
For “Step 2: Choose Object” select an available galaxy. If a galaxy is not available for imaging, you won’t be able to select it. Only galaxies that are visible to the telescopes are available for selection and the available galaxies change throughout the year. In this example, I selected the Andromeda Galaxy, also known as M31:



Click “Find A Mission”:

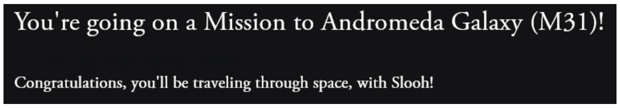


Slooh finds an available telescope and time slot and shows you the result:



Take note of the date and time of the mission (it could be scheduled for the following night). Click “Schedule Mission” to accept the mission.

The following indicates that your reservation is confirmed:



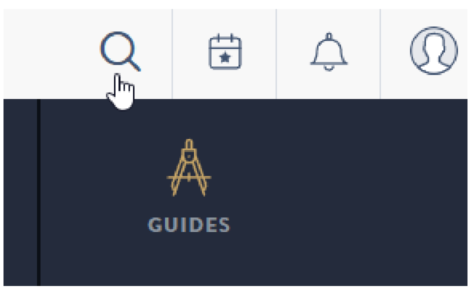
Click “Go Back” at the top left of the page to return to the Mission Setup screen.

Congratulations – you’ve scheduled your first mission! Now we’ll continue by seeing what else we can do with Slooh while we wait for our image.

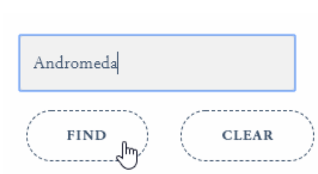
Read a Guide About Celestial Objects

Guides provide you with information on a broad range of topics and go well beyond what you might find elsewhere on the internet. You can find Guides by clicking the Menu icon at the upper left of the screen, and then click Guides. But here, I’m going to show you how to search for a specific object.

Click the magnifying glass icon at the top right of all pages on Slooh:



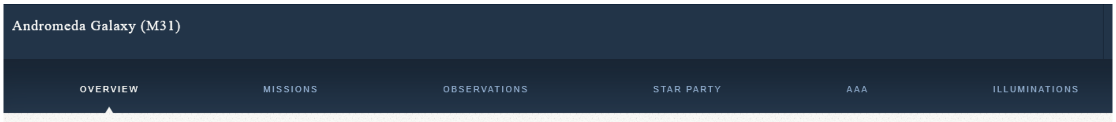
Type “Andromeda” as shown and click “Find”



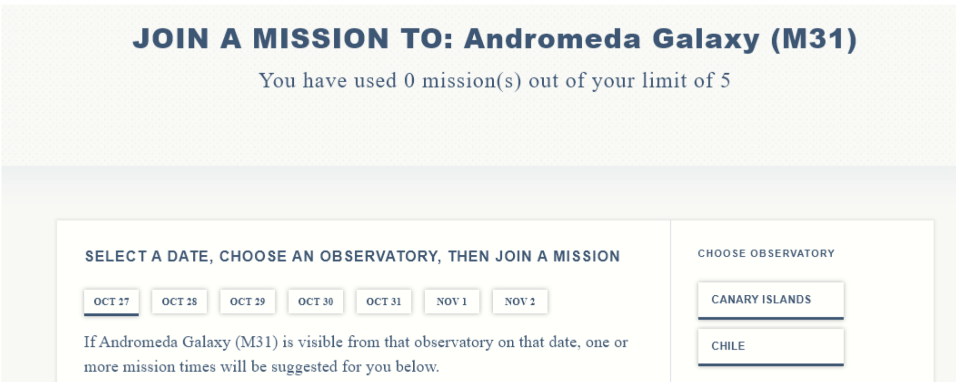
We’re interested in the Andromeda Galaxy, so click the top search result, as shown:

Scroll through the page to find out interesting details about this galaxy, like which telescope is best suited for imaging it, its rise and set times, a link to a related Star Party, and a link to the related Guide. You can click through the various options to explore them.

Go back to the top of the screen and note that there are several tabs across the top:

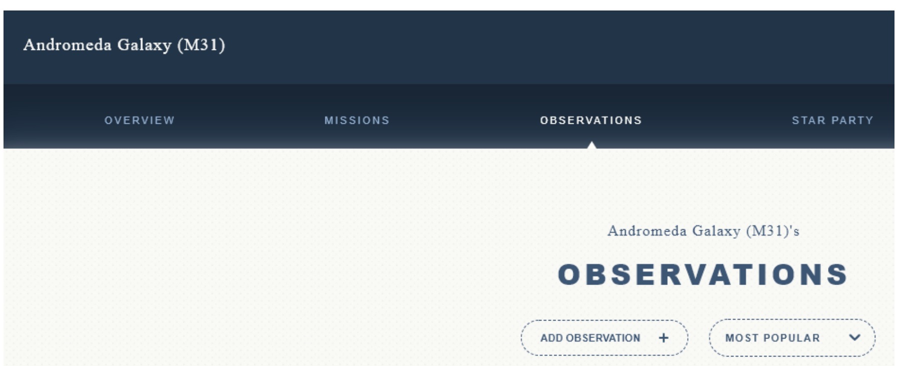


Click the “Missions” tab to view reservations other members have for this object as shown:

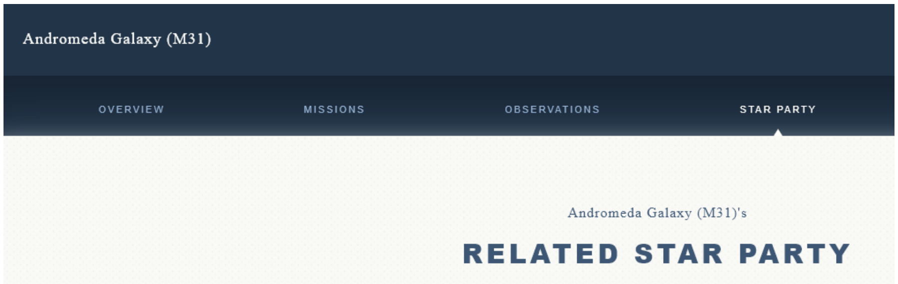


From here, you can Join another member’s mission or schedule a mission – just click the appropriate button.

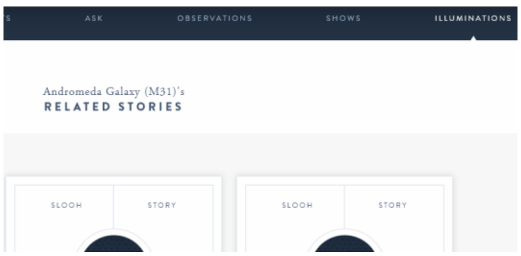
Click Observations to see available the latest Observations members have shared:



Click ‘Star Party’ to see related past Star Parties that featured this object:



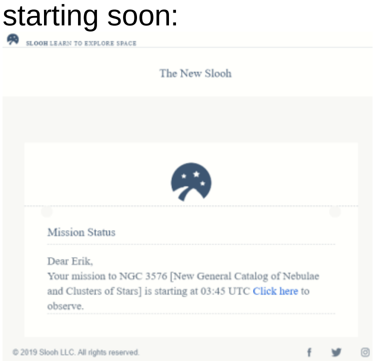
Click “Illuminations” for stories, both fiction and nonfiction, about this object:



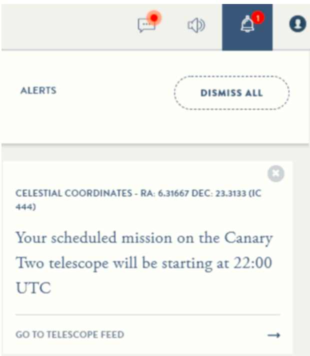
Getting Mission Updates

If you’re patient, you could wait for Slooh to capture your image but you don’t have to wait around. Explore the Slooh website, go to bed, maybe go to work, and check your email.

About 15 minutes before you mission starts, you’ll get an email alerting you that your mission is starting soon:



You’ll also get an Alert notification (click the bell icon at the top right to view Alerts).



Note that old alerts for missions that have completed get removed from your Alerts window, so you won't see a flood of out of date alerts if you visit Slooh after your mission completes.

Some time after your mission completes, you'll get an email the following day which is similar to the following:

Status of your missions

Dear Erik,
Here is the status of your Slooh missions last night:

- Your mission to Messier 31 at 2019-06-25 02:05:00 UTC on the Slooh Canary Islands: Canary Two telescope is complete
- Your mission to Andromeda Galaxy at 2019-06-25 02:45:00 UTC on the Slooh Canary Islands: Canary Two telescope is complete

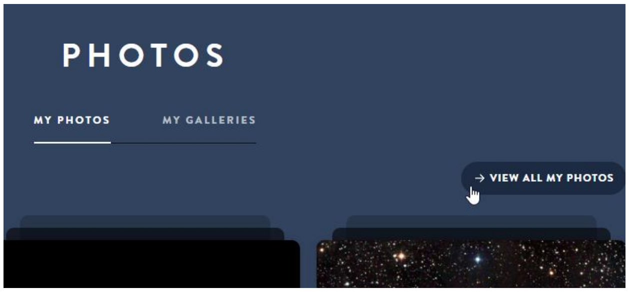
The email says our missions completed successfully and we can now view the result.

Note that you don't have to wait for the email to view your images. If you're watching the telescopes live or waiting for Slooh to capture the image, your image may not be available immediately after the mission completes – you may have to wait some more time for processing to complete, which can be several hours if Slooh has a lot of images to process.

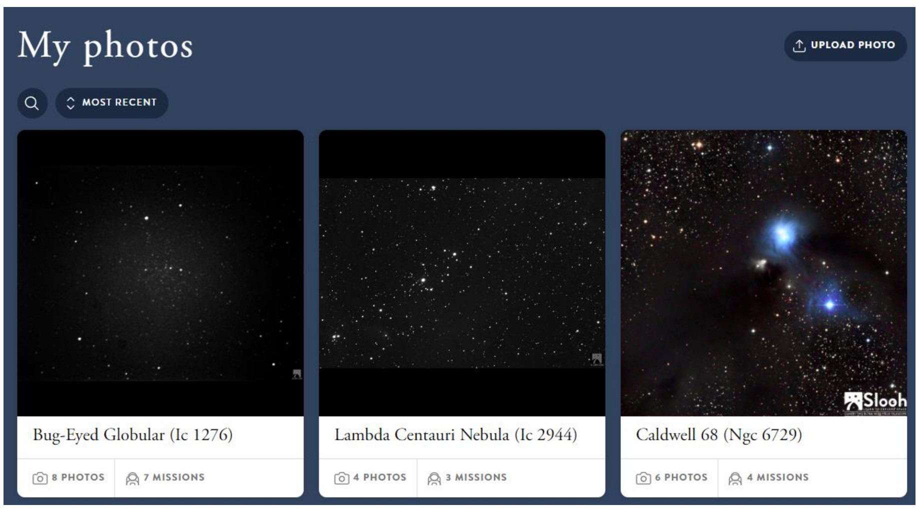
Viewing Your Images

You can check "My Photos" to find your images either once your mission completes, or once you have taken a snap from the live feed.

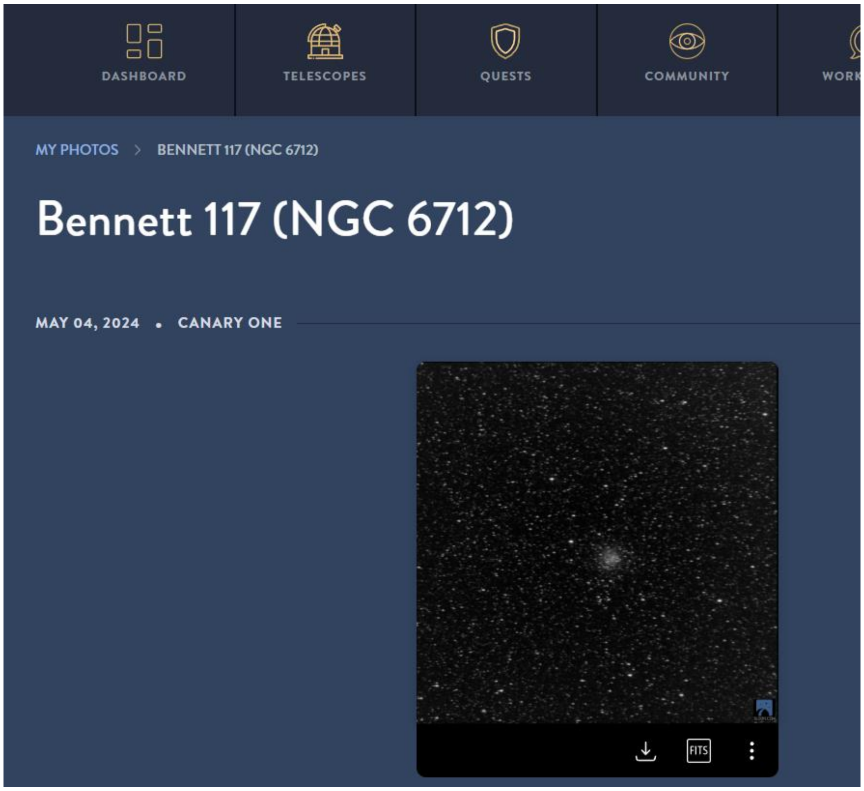
Click the *Dashboard* icon at the top of your screen, scroll down to *Photos*, and click *View All My Photos*:



A screen similar to the following will come up and if there are images available, you'll be able to view them right away:

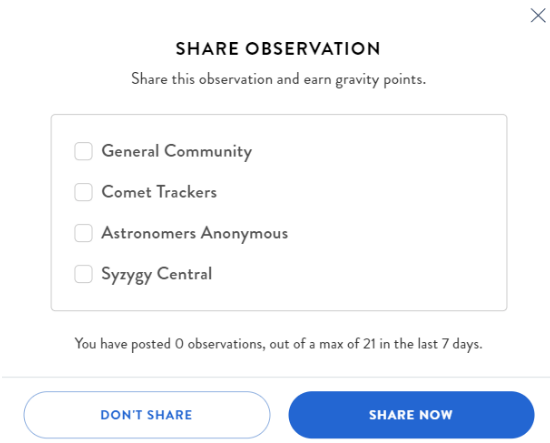


Once you find an image you like, click the image tile and you'll be presented with a screen that contains all of your images related to the one you clicked. For example, if you selected the image of M 31, and clicked its tile, you'd see all of the images that you captured of M 31.



Find an image on this screen that you like and click it; you're presented with a larger view of your selected image:

If you really like the image and are inspired to write something unique about it, you can share your image and words with the Slooh community by clicking the *Write Observation* button at the image's top right side, fill in the form, and then click *Save*. You'll be presented with the following screen:

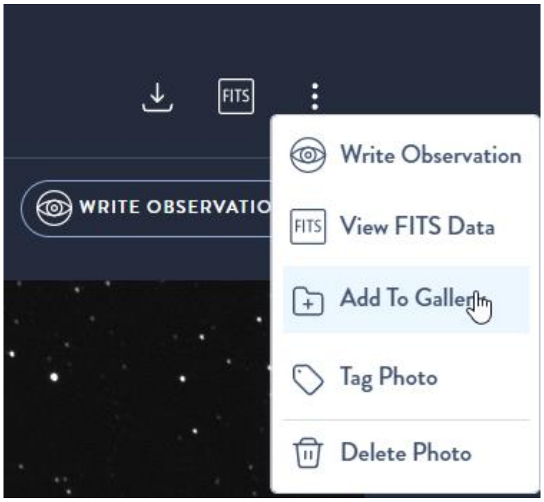


If you click *Don't Share*, Slooh will save whatever you typed into the fields, allowing you to go back later. If you click *Share Now*, Slooh will ask you to select a community - simply choose *General Community* and your observation will be shared with the broader Slooh community. Once your image gets at least 10 Likes, it will show up in the Featured Observations area under the *Community* icon at the top of the Slooh screen.

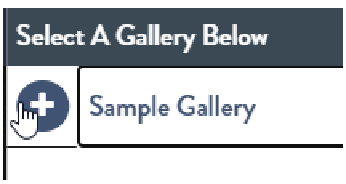
Above and to the right of your image are some action buttons:

Click the  download button to download a full-resolution copy of the image that's on the screen. Your image is downloaded to your computer as a PNG image, which you can view just by double-clicking. A variety of software is also capable of viewing and editing images.

You can add your image to a Gallery, which is like an album, by clicking the third icon from the left at top right of the page and select *Add To Gallery*:

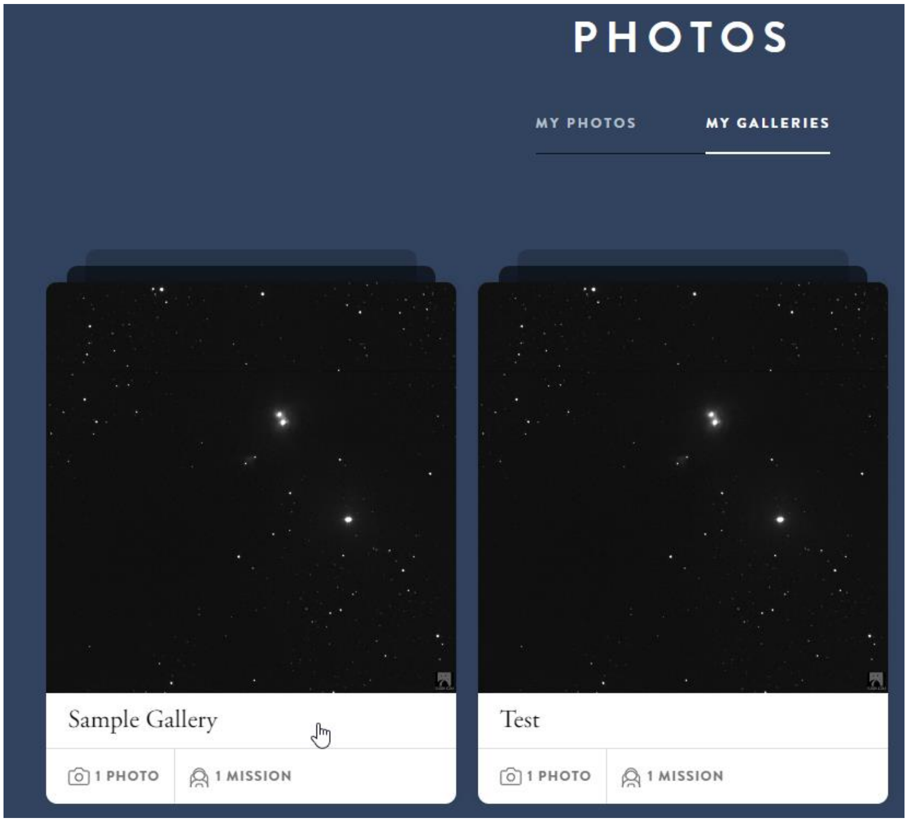


You'll see another small box pop up, which allows you to not only select a gallery, but also allows you to add a new gallery. To select a gallery, simply click its name, and Slooh will add your image to the selected gallery. To create a new gallery, type the name of the new gallery in the topmost box (see screenshot) and click the plus button:



Slooh creates an empty gallery for you – add your image to the gallery by clicking the new gallery's name.

You can view Galleries you create by clicking the *My Galleries* tab at the top of the *Photos* section of your Dashboard.



In the future, you will be able to share Galleries with other members, and perhaps share them with people outside of Slooh as well.

This concludes the Quick Start Tutorial.

You now know enough about using Slooh to schedule your own missions and explore what's available. But there's much more to Slooh, so read on to find out more exciting and interesting ways to use Slooh!

Understanding Slooh

What attracted me to Slooh initially was that it made it possible to use a remote observatory, featuring amazing telescopes and automation, and located in sites around the world having great seeing conditions. I was originally attracted to remote observing through a service called the MicroObservatory – I discuss this in the section "My History with Astronomy and How I Found Slooh".

But there's more to Slooh than imaging.

Slooh fills three roles:

- Education
- Community
- Imaging

This section discusses each of these roles in detail.

Understanding Slooh for Education

Slooh was awarded a grant by the U.S. National Science Foundation whose goal is, in part, to promote the progress of science. The grant was a milestone because it was used to develop education programs unique to the Slooh platform.

Slooh offers many avenues towards education including:

- Guides – detailed guides that teach you about famous astronomers, galaxies, telescopes, planets, small solar system bodies and many other topics. Each guide is subdivided into subtopics that go into detail about specific areas. You can save guides to your reading list for quick access later.
- Quests – these are challenges that help you explore space in fun and engaging ways. Participants earn badges and Gravity Points, both of which form part of their profile in the community.
- Star Party – broadcasts about various aspects of Slooh and astronomical topics in general.

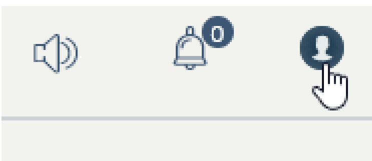
In addition, Slooh offers Teacher and Student memberships that schools can use as part of their curriculum.

Understanding Slooh's Community

Slooh has an active base of users who use the telescopes daily. Just browse through the queue of reservations for the telescopes, and you'll start to come across names that appear regularly (you can see the names of people who have reserved time on the telescopes). However, the community is much more than regular users of the telescopes—you can interact with those members and others.

Slooh offers exciting and engaging communities using Discord Servers. A Discord Server is a community of users that interact with one another through voice, text chat, and media and files. Discord is a free third-party service that is integrated with Slooh.

You start by creating a new account on Discord and you do that by clicking the Account icon at the top right of any Slooh screen, the icon is shown in the following screenshot:



From there, click the *My Community* option and then click the link shown in the following screenshot:

Once you have created your account on Discord, return to the *My Community* page and click the *Join Discord Server* button, which will automatically link your new Discord account with your Slooh account.

From there, you can select which Houses you want to Join. A House is a subset of the Slooh community that is focused on a certain aspect of astronomy or activity. For example, the Pyxis house is a learning area where members interact by discussing things they have seen on Slooh, astronomy Q&A, and solar chat which focuses on the Slooh Canary 5 Solar Telescope.

There are several other Houses, and I am the leader of the Fornax house, which focuses on image processing and features a showcase where you can display Slooh images you created.

Slooh has created a short video tutorial on using Slooh with Discord and you can access the video here:

https://youtu.be/1CkEiD0oois

Understanding Community Workspaces

A Slooh Workspace is a place where members of the community can interact with one another, and there are several workspaces; however, the Astronomers Anonymous Workspace is the default one of which everyone is a member. Click the Discussions tab below the workspace name and you can participate in discussions that are happening there.

Understanding The Role Of Slooh In Imaging

There's nothing quite like having your own telescope before you, pointing it to wherever you like, and viewing the night sky.

For astroimaging, you need a camera along with your telescope. You'll also need a mount to assist in pointing the telescope, plus software to help you drive everything. In astroimaging, the details matter, and while a regular DSLR camera will do in many cases, once you get to a certain point, you'll find that you need a dedicated astroimaging camera. You also need software to help you manage the camera.

Once you have all that equipment, you need an observation site. Ideally, you want a site with great viewing conditions, dark skies, and little to no light pollution. You also want a location with reasonably good weather to maximize the number of viewing nights available to you.

Ideally, you want to automate everything. While staying up late is nice some nights, it's not practical when you have a job or other commitments, so automation is key. It would be best to set up whatever you want to view and then have the results delivered to you the next day.

In addition, you need something to look at, so you have to research possible targets that suit your telescope and determine when they're visible in the sky for imaging.

In the last four paragraphs, I described everything that Slooh provides in terms of imaging.

Slooh handles all of the details about the observing site, managing the telescopes and cameras, installing software, and all the rest for you. Plus, they automate everything, so all you do is make reservations and get your images and data the following day.

So how does Slooh fit into an astronomer's hobby?

- Slooh can augment the number of viewing nights available to you
- You can use Slooh for research
- You can use Slooh to image targets that are too dim for your telescope or seeing conditions
- You can use Slooh to access observing sites that are far away and in ideal seeing conditions
- You can take great photos with Slooh
- Slooh has a great community of users and astronomers
- Slooh provides lots of opportunities for education and for educators
- Slooh participates in outreach and education programs

I use Slooh to expand my knowledge of space, to participate in an active community, and to contribute. I can do more with Slooh than with other imaging services that provide remote telescopes and a knowledge base for me to search when I run into problems.

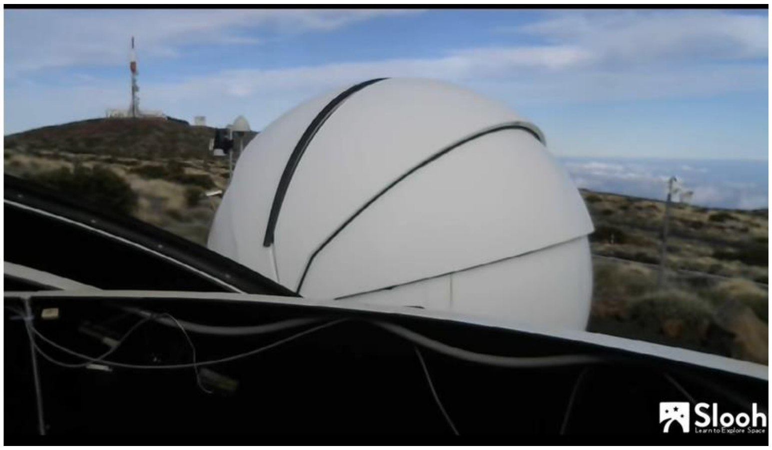
Understanding The Slooh Telescopes

Slooh currently offers its members the use of nine different telescopes - that's an incredible array of choices. The number of telescopes is planned to increase with the addition of several more telescopes at a new observing site sometime in the future.

This section discusses the telescopes and some of their features.

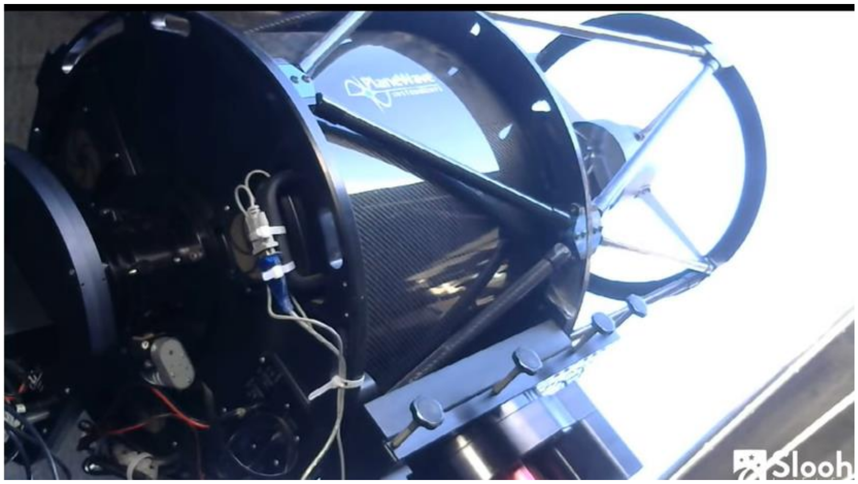
This is a view of the Canary Islands domes, taken from a recent 360 tour Slooh offered its members:

You can see one of the domes is partially open in the above picture. Here's a view of Dome Two:



The image of Dome Two was taken while it was closed and was taken from Dome One, which you can see in the foreground of the preceding picture.

This is the popular Canary One telescope:



The telescope has an aperture of 508mm, which is really big. It lets in a lot of light and is great for all sorts of targets. Here's an image of the CCD camera attached to the telescope:

The camera needs to be kept very cold to minimize noise—it is cooled to about -35 degrees Celsius during missions. The person in the image on the left (Paul Cox, who handles most of Slooh's operations and is an active member of the community) can give you an idea of the size of the components.

I discuss what a CCD is and how it works in the "Understanding Calibration" section in the "Understanding Color and Filters" chapter.

Canary One is ideal for faint objects like galaxies and nebulae. I have used it for all sorts of deep-sky observations.

Here’s a view of the Canary Two telescope:

Canary Two offers two telescopes - a wide field and an ultra-wide field telescope. You’ll see the difference in views when we start using the planetarium software for mission planning later on I discuss the difference in views in the section called, “Using KStars To Plan And Schedule A Mission”.

These telescopes are great for capturing larger objects but it’s also great for comets and globular clusters.

Here’s a view of three telescopes: Canary Three, Four, and Five in the open dome:

Canary Three is a deep sky telescope that provides a very wide field of view ideal for larger galaxies and nebulae. It features a single-shot color camera which takes images in color, unlike the other telescopes that take images in color using separate images. Refer to the section Understanding The Filters Slooh Uses for details about filters and images.

Canary Four offers the smallest field of view of all the telescopes and is optimized for viewing solar system objects and smaller bodies like planetary nebulae.

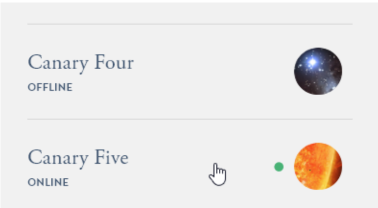
The Chile site has two telescopes. Chile One telescope has wide field is ideal for capturing galaxies and nebulae as well as globular clusters.

Chile Two, pictured below, is similar to the Canary Two telescope and can capture all sorts of astronomical objects, from the moon to faint and distant quasars.

Understanding the Solar Telescope – Canary Five

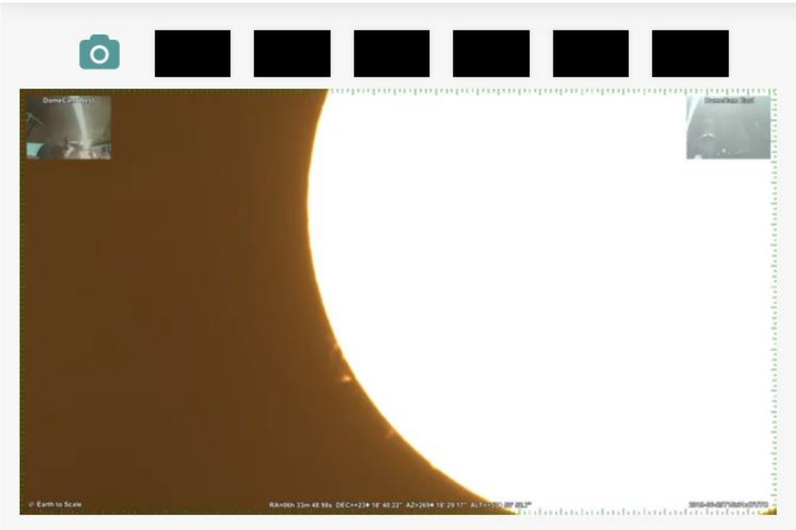
The Slooh Canary Five telescope, or Solar telescope, is very different from the other telescopes. The most obvious difference is that this telescope is available during the day and is focused on the Sun. In addition, you cannot reserve this telescope like the others, and the files it produces are different from the others.

The Solar Telescope is often open during the day when the other telescopes are closed. You access the telescope using the Slooh interface as shown (click the *Telescopes* icon at the top of your screen and select Canary Five):



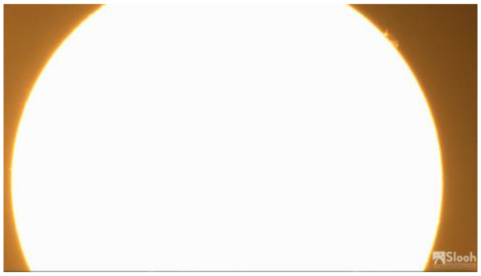
In the screenshot, Canary Five is online because it has the green dot next to it. The other telescopes are closed because it's daytime.

When you navigate to the telescope, you're presented with a window with a picture of the Sun in it, as shown:



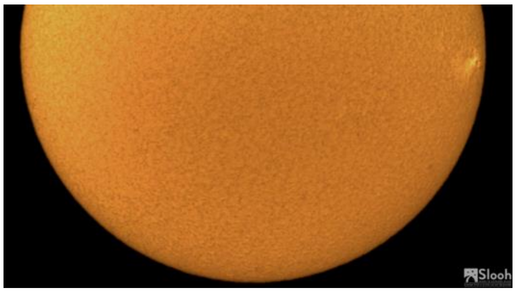
The window is actually a video player, showing the Sun as it appears in the video feed from the camera attached to the telescope. You might have to click the Play button in the center of the video window to view the live video feed.

Depending on what's happening on the Sun the day you view the feed, you might see one of two views. This is one view of the Sun as a bright disk:



The telescope in this image is tuned to highlight the areas around the Sun – you can see prominences at the upper-right corner of the Sun in this image.

Alternately the telescope could be tuned to show surface features like this:



In this case, the Sun looks much like an orange. In this image, a rare sunspot is shown (it's called AR 2733).

Above the video, you have a camera icon with several open slots. Click the camera icon to take a picture from the video feed.

Images you take here appear in your dashboard's *Photos* area.

You can download your images of the Sun from the *Photos* area and use them to do additional processing on them if you like. Slooh produces a PNG file for you. Refer to the section called <u>Viewing, Uploading and </u>Downloading Images for information on accessing your images.

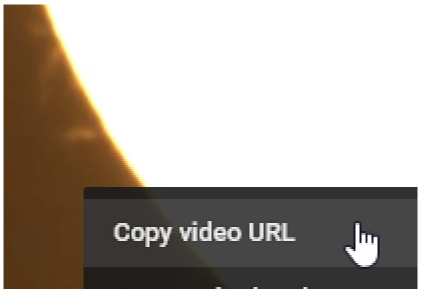
If you look closely at the live feed, you'll notice a couple of overlays in the window. These overlays don't show up in the images you take but provide some interesting information:

- At the top left is a live image of the dome from the west.
- At the top right is a live image of the telescope as seen from the dome on the east.

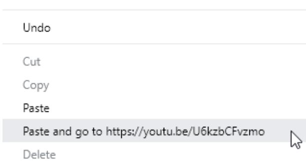
- At the bottom left is a scale image of the Earth so you can get an idea of the scale of features on the Sun.
- At the bottom center is the Sun's celestial coordinates in RA/Dec and Alt/Az.
- At the bottom right is the current time in UTC.

You can make this image full screen if you like – use the following steps:

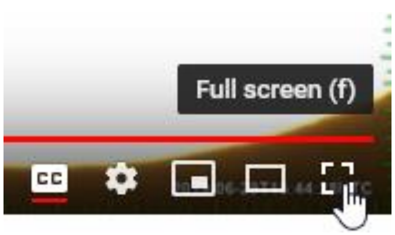
1. Right-click the video and select "Copy video URL" as shown:



2. Open a new tab in your browser and paste the video URL into the address bar:



3. Click the "Full Screen" button at the bottom-right side as shown:



You can exit full screen mode by pressing the ESC key on your keyboard.

As I mentioned earlier, you cannot reserve time on this telescope because it provides you with a live feed, so the only way to capture images from the telescope is when it is open and capturing images. Unfortunately, that makes this telescope inconvenient for those in varying time zones because it could be late at night for you when the telescope is open. Fortunately, Slooh members often share their images of the Sun in the Community Observations (you can access Slooh's community by clicking the Community icon at the top of the Slooh screen).

Summary of Slooh Reservable Telescopes

The following table lists the details of each reservable telescope.

FOV=Field of View; Resolution in pixels.

Telescope Name	**Details**	**Comments**
Canary One Half Meter Telescope	Aperture: 508mm FOV: 0deg 37’ 00” x 0deg 37’ 00” Resolution 3056×3056	
Canary Two Wide-Field Telescope	Aperture: 432mm FOV: 0deg 43’ 00” x 0deg 43’ 00” Resolution 4096×4096	
Canary Two Ultra-Wide-Field Telescope	Aperture: 85mm FOV: 1deg 47’ 06” x 1deg 12’ 12” Resolution 2184×1472	This telescope takes images at the same time as Canary Two Wide Field and you get the FITS files for both telescopes
Canary Three Deep Sky Astrograph Telescope	Aperture: 279mm FOV: 1deg 39’ 14” x 1deg 14’ 56” Resolution 3357×2535	This telescope as a one-shot color (OSC) camera attached to it
Canary Four Solar System Telescope	Aperture: 355mm FOV: 0deg 15’ 57” x 0deg 12’ 03” Resolution 3358×2536	
Chile One Wide-Field Telescope	Aperture: 355.6mm FOV: 0deg 31’ 18” x 0deg 20’ 51” Resolution 3358×2536	
Chile Two Wide-Field Telescope	Aperture: 432mm FOV: 0deg 43’ 00” x 0deg 43’ 00” Resolution 4096×4096	This telescope is similar to the Canary Two telescope

What People Use Slooh For

Given that there’s so much choice not only in the telescopes Slooh offers, but also so much choice in terms of outreach and education, there are lots of possibilities, some of which I have already mentioned – here are some more uses of Slooh:

- Research
- Comet hunting
- Asteroid hunting
- Advanced astrophotography
- Deep sky observations
- Observe the Sun
- Opportunity to contribute to community projects
- Opportunity to learn based on Slooh's webcasts, videos, and guides
- Participation in the active community
- To get more viewing nights which might not be possible with your own telescope
- Do advanced image processing

Understanding Slooh Membership Levels

There are several membership levels open to the public including some that aren't visible on the website. For families, or any small group, Slooh offers the Family membership that includes one main account and four sub accounts. For teachers, Slooh offers the Teacher and Student account; I don't discuss the details of the Teacher and Student accounts in this book directly; however, the functions are similar to the Family account, except that the Teacher account has access certain Student account aspects that make it easier to administer a curriculum.

Understanding the Family Membership

The Family membership provides you with one main account and four sub accounts. The main account allows members access to Slooh, the Guides, Clubs, Shows, Quests Illuminations, Photos, and the live telescope feeds.

The main account can book missions using all of the reservation methods. I explain the booking methods in the section called "Mission Planning and Booking". Apprentice members also have access to the Join Mission Feature (explained in the section called Understanding Joining Missions). The main account has the following capabilities:

- Can have up to one reservation at a time
- Can have up to five Join missions at a time
- Access to FITS files from missions
- Have access to four catalogs when booking missions "By Catalog" – these catalogs include over 8,000 celestial objects
- Can post up to seven Observations per seven day period

The sub accounts of the family membership can book missions using all of the reservation methods. The sub accounts have the following capabilities:

- Can have up to one reservation at a time
- Can have up to five Join missions at a time
- Have access to four catalogs when booking missions "By Catalog" – these catalogs include over 8,000 celestial objects
- Can post up to seven Observations per seven day period

Understanding Individual Membership Levels

Currently there are two individual membership levels available to the public: Apprentice and Astronomer. You need to contact Slooh support by email to gain access to these membership levels (support@slooh.com).

Understanding Apprentice Membership

Apprentice membership allows members access to Slooh, the Guides, Clubs, Shows, Quests Illuminations, Photos, and the live telescope feeds.

Apprentice members can book missions using all of the reservation methods. I explain the booking methods in the section called "Mission Planning and Booking". Apprentice members also have access to the Join Mission Feature (explained in the section called Understanding Joining Missions). Apprentice members have the following capabilities:

- Apprentice members can have up to one reservation at a time
- Apprentice members can have up to five Join missions at a time
- Apprentice members have access to FITS files from missions
- Apprentice members have access to four catalogs when booking missions "By Catalog" – these catalogs include over 8,000 celestial objects
- Apprentice members can post up to seven Observations per seven day period

Understanding Astronomer Membership

The Astronomer membership level includes all of the access available to Apprentice members, plus some additional capabilities:

- Astronomer members can have up to five reservations at a time
- Astronomer members have access to all catalogs when booking missions "By Catalog"
- Astronomer members have access to the multi-luminance processing recipes
- Astronomer members can post up to 21 Observations per seven day period
- Astronomer members can reserve sessions that are below the *soft horizon* limit of 30 degrees

The ability to reserve up to five reservations at a time is a big advantage, especially when you want to get a lot of exposure time on a target. I use my five reservations to explore the sky for objects I'd like to get a closer look at, and then book five reservations in a row another night to get more exposure time on the targets that interest me.

Access to all catalogs makes booking a breeze. You have access to 18 catalogs, including VDB, UGC, SAO, Sharpless, LBN, and Bennett, as well as NGC, Messier, and IC catalogs.

The multi-luminance processing recipes are great for when you are trying to image faint objects or want to do some science on your images. They're also great for producing superb astronomical images because you get lots of luminance data binned at a high resolution of 2x2 (I discuss binning in the section Understanding Binning).

Understanding Student Membership

Student members are similar to apprentice members in that they can have one reservation at a time, however, Student members do not have access to the FITS data for their missions. Slooh does not produce FITS files for Student members, so if you happen to Join a mission by a Student member, you won't get a copy of the FITS files regardless of your own membership level.

Next Steps

Next, we're going to learn about the tools and workflows you'll use to work with Slooh and the lessons in this book.

Understanding The Tools And Workflows

While it's possible to use Slooh without any additional software, you get a better overall long-term experience with the capabilities the software enables for you.

Planetarium Software

Planetarium software is an application that astronomers use to plan observations, do research, verify photos they have taken, log their observations, and even control the camera and telescope.

Planetarium software contains a database of stars, planets, comets, asteroids, and even satellites. Using the database and some incredible math, the software makes it possible to figure out what's up in the sky on any given night from your location. Some software even allows you to see what the night sky might look like from another galaxy too!

The software is also interactive in that it shows you what the night sky looks like at any time, so it also helps you compose your images before you see them, so there's a lot less guesswork involved in setting up a mission.

You can certainly use Slooh without planetarium software, and I did that at first too. As you'll see later on, you can take advantage of the Slooh 1000 List, a curated listing of the best objects in the night sky, when making a booking. I show you how to use the Slooh 1000 List in the chapter called "Quick Start" and "Understanding the Slooh 1000 List".

Planetarium software comes in handy when you want to advance from the Slooh 1000 List to explore other night sky objects like other nebulae, planetary nebulae, stars, study exoplanets planets, or maybe even track down an asteroid or newly discovered comet.

The planetarium software we use in this book is called KStars, and I walk you through planning missions using it.

Personally, I use TheSkyX which offers the same underlying capabilities but offers more star databases, includes things like "plate solving" (this comes in handy when you're trying to identify things in an image), and other capabilities that are not in KStars. But I like some of KStars features and use it when planning too.

Understanding Online Planning Tools

Later in this book, I walk you through using an online planning tool called Telescopius. It's a free, online tool you can use to plan your observations, much like you would do in planetarium software. So why would you go online when you already have planetarium software?

Tools like Telescopius have an easy-to-use interface that makes it easy to track down objects of interest just using just a few clicks. You can sort or filter by magnitude, elevation, and a variety of other attributes like object type and more.

In addition, some planning tools help you narrow down things to view very quickly. For example, I can quickly get an idea of what comets are available to me to view using one online tool that's always up to date. And that's actually a very important feature of online tools - freshness of data.

As I mentioned earlier, planetarium software uses a database of stars and other objects as the basis for its functionality. While the stars, nebulae, galaxies, and other objects don't move (much), other things change position quite a bit. For example, comets, asteroids, and planets change position all the time. Planetarium software uses data from publicly available sources to be able to display these objects and their paths to you; however, you need to make sure the database is always up to date. This is true in the case of asteroids and comets, some of which are being discovered on a regular basis.

While it's easy to update the planetarium software's database, it's also easy to forget, leading to unsatisfactory results when planning an observing session. An online service always has the most current data, so you can be assured that you'll get the best possible results.

The online tools I highlight here are free to use and may only require your email to sign up.

Understanding Imaging Tools

Since Slooh generates images for you to use directly, and does a good job of creating them, you can certainly use Slooh without any imaging tools beyond those installed with Windows (like Paint and the integrated Windows Photo Viewer).

However, there are cases where you'll probably want to edit the images you get from Slooh.

Consider this image of the Andromeda Galaxy:

The image is from the Canary Three telescope and shows a large, bright core with faint edges.

Here's the same image that has been processed using various imaging tools:

In this image, the core is not as over-exposed as it was in the original, plus you can see the fainter edges of the galaxy. You can also resolve the dust lanes. It's clearly a nicer picture. Not only that, it's also more useful since you can now resolve so much more than in the original image. You could study the image in more detail, perhaps explore the core, and maybe compare the brightness of Andromeda with the brightness of the nearby galaxy, M 32 which is the bright area just below Andromeda.

As part of your astroimaging adventure, you'll eventually get to the point where you want to produce better and more useful images.

In this book, I have you use several imaging tools: DeepSkyStacker, AstroImageJ, and Photopea,com.

DeepSkyStacker is used to work with the FITS files you get from Slooh (I go into details about what these files are and why you need them later in the Image Processing section).

AstroImageJ is software that's specialized for photometry, or the measurement of photons from your images. However, you can also use it to create final images and perform quick manipulations.

Understanding The Term Workflow

When researching using forums and online communities you'll often come across the term "workflow".

A workflow, as far as astroimaging is concerned, is the steps someone uses to process an image.

For people that have their own telescopes and don't use Slooh, their workflow often includes something called "calibration". You can ignore things related to calibration because Slooh provides calibrated images to you (I explain what this means in more detail in the section Understanding Calibration).

What I show you in this book are a few different possible workflows and you are certainly free to modify them or create your own. My goal is to give you a good starting point and make the overall process of finding your own workflows easier.

Next Steps

Now that you're familiar with the tools and workflows, let's jump right in and book some missions using the Slooh telescopes!

Before we do that, go ahead and install and configure the software that I'll show you how to use throughout this book. Skip ahead to the section near the end called "Software Installation and Configuration" and then come back here.

If you want to skip software installation, that's no problem since I show you how to use Slooh without using any additional software too. I highlight when you'll need the extra software as we go along.

Part I: The Slooh.com Dashboard

Understanding the Slooh.com Dashboard

The Slooh dashboard appears as soon as you log in or when you click the Slooh logo at the upper left of any page.

Slooh.com is primarily a community of astronomers at all levels. It makes learning about astronomy fun and engaging through Gravity Points. You earn gravity points by going about your day-to-day activities on Slooh.com: booking missions, posting questions, sharing observations, liking posts and observations, completing quests, and more. The Slooh.com Dashboard is a window into all of the activities you can perform at Slooh.com in one place.

The Dashboard consolidates a lot of functionality that used to be in different places throughout Slooh.com. It also helps you understand your own gravity points and the gravity points of the overall community. With that understanding, you can measure your engagement with the community, and that information is updated in real time.

The Dashboard has a lot of functionality in it – this section describes each section and how you can access the equivalent functionality using the Slooh menus, if available.

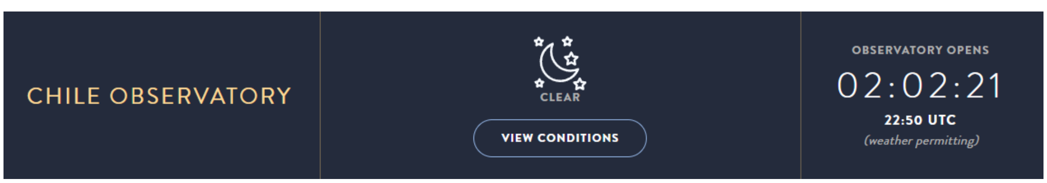
The Star Party Section

The very first section is the Star Party section, which shows either upcoming star parties or recently published recordings. If you click the Join Star Party button, depending on whether the event has already happened, you'll be taken to the event page, where you can either join the party or watch the recording. You can get to the listing of all star parties by clicking Community at the top of the Slooh page, and clicking the Star Parties tab to view the categorized listing.

The Telescopes Section

The Telescopes section lists the available observatories that Slooh provides. This section provides you with information about the observatory's status, its hours, and details about the weather and sky rating all in one place.

If the observatory is offline, you'll see something like this:



The *View Conditions* button takes you to the telescope's page, where you can review weather conditions.

If the observatory is online, you'll see something similar to the following:

The buttons on the right side take you to the live telescope view and the information on the left side provides you with information about sunrise, sunset, as well as current imaging and weather conditions.

Using the Missions Section

The mission section starts with an area where you can schedule missions – click the *Schedule Mission* button to access the mission scheduler.

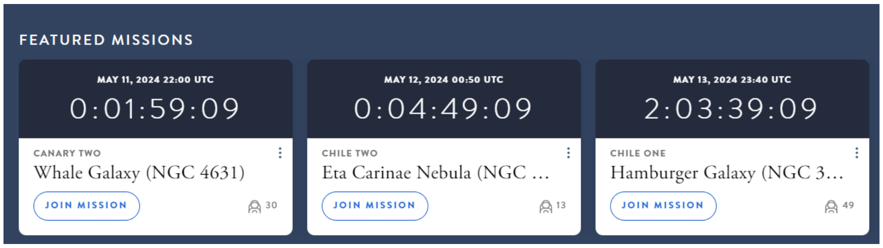
If you have one or more reservations pending, you'll see them in boxes next. Each box has a three-dot menu at its upper-right side. If you click the three-dot menu, you'll see three options:

- Cancel Reservation – cancels the currently selected reservation
- View Object Guide – takes you to the object's Guide page where you can read more about the mission's target
- View Telescope Guide – takes you to the telescope Guide page, where you can find out more about the telescope that the mission is using

If you don't have any pending missions, you'll see a link to the Slooh support website that explains how to book telescope time.

The Featured Missions Section

The Missions section lists Featured Missions as selected by Slooh staff:

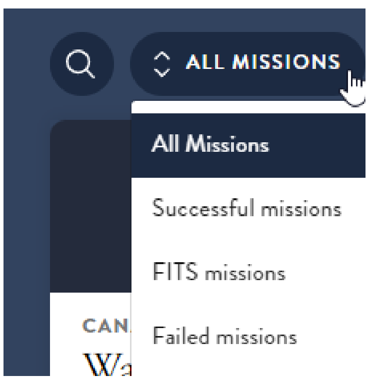


You can click the 'Join Mission' button to join the mission. You'll receive the images from it in your My Photos area when it is completed.

Using the My Past Missions Section

This section lists recent missions you booked—you'll see both failed and successful missions here. You can go to the details of the mission by clicking its *View Mission Log* button. Alternatively, you can get a listing of all your past missions by clicking the *View All My Past Missions* button.

The *My Past Missions* section focuses on one mission at a time, unlike the *Photos* section, which focuses on one object at a time. A button next to search, labeled *All Missions*, allows you to filter missions based on success or failure and allows you to filter missions that have FITS files:



The Quests Section

Quests, unique to Slooh.com, are interactive learning activities that encourage you to use the Slooh platform to collect images to complete learning objectives. Quests are engaging, well-organized journeys. They allow users to use the Sloph telescopes and platform to capture stunning photos of space objects. These Quests span across various subjects, from astronomy to arts, and more. The interactive nature of these lessons keeps users excited about learning as they gather and analyze data to draw their own conclusions. Over 60 interactive lessons challenge members to use Slooh to collect and analyze data to form their own conclusions.

You can use the Browse Quests button to view all available Quests. On the All Quests screen, you can filter Quests by clicking the All Categories option and then selecting one or more filter criteria. You can view Quests that you're currently working on by clicking the My Quests tab under Quests, and you can view complete ed Quests by clicking the Completed Quests tabs in the Quests section.

Using the Photos Section

The Photos section consolidates many features and is the primary place from where you retrieve photos from your reserved or Joined missions.

The first thing you see below the Photos heading is two tabs: *My Photos* and *My Galleries*. My Photos is the default tab and shows you all of your past photos. The My Galleries tab displays Galleries you have created. Currently, there is no more functionality beyond creating, deleting, and editing Galleries—you cannot share a Gallery, and there aren't any other functions you can perform using a Gallery. If you wish to arrange it that way, it can act as an album.
Two buttons above the tiles show photos from past missions: *Upload Photo* and *View All My Photos*.

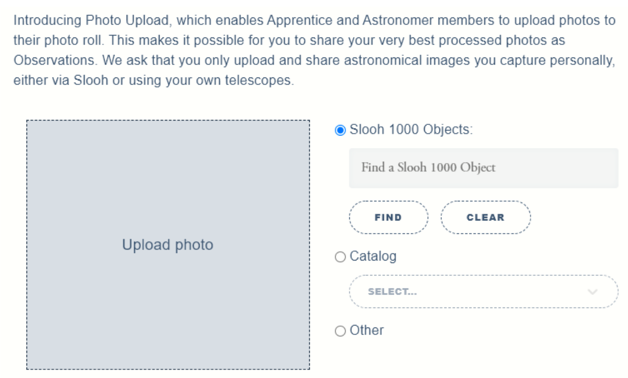
The *Upload Photo* button is your gateway to three powerful actions – uploading a photo, identifying the object in the photo, and recording the observation log – the descriptive text you see below a member's shared photos. I discuss uploading and downloading photos in Uploading and Downloading Photos.

Three images appear below the buttons. These are the three most recent images you have captured, and you can see all of your images by clicking the *View All My Photos* button. Note that the Photos section focuses on the object, so when you select a photo to view, you'll see all of the photos associated with that object, not just the most recent one. This focus on the object can be convenient, especially if you're trying to find old photos of a particular object. The downside is that you cannot currently search for your object – the only way to find one is to go through your previous photos, which can be tedious. This is why it is recommended that you download your photos as soon as possible, to avoid a situation where you must review many pages of old photos looking for an object you imaged some time ago.

Below the three photos is the Slooh 1k Challenge button where you can View the Slooh 1k. The Slooh 1000 is both a listing of the best objects in the night sky and a way to challenge yourself. The Slooh 1000 listing maintains a record of the objects you have and have not observed, and you can filter based on objects that have images and those that do not. Many members use the "do not have images" listing as a challenge to collect all 1000 objects on the Slooh 1000 listing. When you click the View the Slooh 1k button, you're presented with an overview of Slooh 1000 objects visible on the current date. You can pan around the map by clicking, dragging, and zooming in and out using your mouse's scroll wheel or the controls at the map's upper right. You can click any objects to learn more about them, plan a mission, or view images you have previously taken using the Slooh telescopes. The large grey patches on the map's left and right are areas not visible by the Slooh telescopes. You can filter the objects using the selections above the map, including filtering my objects with and without images. You can also view the Slooh 1000 or 100 using the toggle switch on the right side, above the map. If you click an object, you get two more options: plan a mission and view a guide, which is very helpful when researching. The mission planner goes to the object page and allows you to schedule a mission easily; the object guide is useful for investigating an object's background information.

Uploading a Photo

You can upload photos to share them with the community or just store them in your photo roll. Click the 'Upload Photo' button to start the upload process:



Click the 'Upload photo' label in the box to select a photo to upload. Once uploaded, you can identify the object as a Slooh 1000 object, a Catalog object, or some other object.
For Slooh 1000 objects, enter the common name in the Find box, click 'Find', and select the correct object.

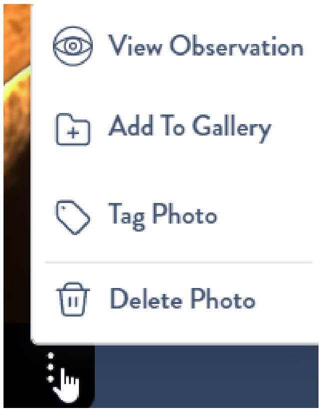
For Catalog objects, click Catalog, select the correct catalog and enter the designation in the box provided.

If the object cannot be classified as a Slooh 1000 or Catalog object, select Other.
You can optionally give your object a title and provide a description.

Click 'Upload Selected Photo' to upload it to your photo roll.

If you want to share your uploaded photo, click the three-dot menu, and then select 'Write Observation' (you need to select this even if you have already written something). From there, click the Save button, followed by the Share Now button. Once your photo receives at least 10 Likes, you'll see it on the dashboard in the Community section.

If you click the three-dot menu, you'll see options for adding the photo to a gallery (this is where you can also create a new gallery), tag, and delete the photo:



Using the Observations Section

The Observations section shows observations members have shared.

For your observation to show up under the Featured tab, at least 10 other users must Like your photo. Here you can view the image, read the description, and find out some more about the member that shared the image based on the icons below the text. You can also Like and comment on the image you see. You can scroll right and left using the arrows on either side of the image. Select the All option to view all of the images other Slooh members have uploaded (your uploaded image shows up here first, and once it receives 10 Likes, it shows up under the Featured option).

You can also view your previously shared observations – click the My Observations tab under Observations to view your most popular observations – click the Most Popular option to reveal the Recent option, which shows your observations by date shared.

What's Next

Now that you understand the dashboard, the next section describes mission planning and booking.

Part II: Mission Planning And Booking

Mission Planning and Booking

The night sky is always changing. People often navigate the sky using constellations and these constellations change based on the time of night and even change according to the season. Some constellations are always up in the sky because they're close to the North Star, which never sets in the northern hemisphere. In the southern hemisphere, there are three constellations that are always up because they're close to the star Sigma Octantis.

Keeping these exceptions in mind, the remaining constellations rise and set throughout the night and the constellations available for you to see change throughout the year. For example, the constellation Orion is visible in the northern hemisphere during the winter months but it's not at all visible during the summer.

Given that the entire night sky is available to you when you plan an observation, how do you know what to view when you book a mission? This is where Slooh and some of the software you installed earlier come in.

This chapter explains and walks you through booking missions using the Slooh 1000 list, catalog missions and, for Apprentice and Astronomer members, you'll learn how to use KStars to plan a mission, and you'll do an advanced coordinate mission to get just the right shot of a grouping of galaxies.

Understanding Slooh Time – UTC

Before you begin booking a mission or using the telescopes, you first need to understand the time zone Slooh uses for all of its telescopes.

The Canary Islands are located off the west coast of Africa and the Chile is on the west coast of South America so the time zones for each location vary quite a bit. To make things easier to understand, Slooh schedules everything using UTC, or Coordinated Universal Time. UTC is also referred to as GMT, international time, and world time – it's the time zone used to derive time for the rest of the world.

When you book a mission using one of the telescopes, you'll see the time of the reservation in UTC along with two other time zones. The extra time zones are there for the convenience of a lot of members that live within those time zones; however, the reservation is based on UTC.

When I have you setup the planetarium software, I have you set the time zone offset for the Canary Islands to zero hours from UTC so that all of the times you see are based on the time Slooh uses.

Also note that Slooh displays the current UTC time near the top-left corner of all screens.

Understanding and Using The Slooh 1000 List

The quickest way to book an observation session, or mission, is to use the Slooh 1000 List (Apprentice members have access to some catalogs, whereas Astronomer members have access to the Slooh 1000 list and all catalogs).

The Slooh 1000 List is a curated a list of 1000 objects in the sky that make for great looking photos. The list was compiled by the professional astronomers at Slooh with input from the community. The Slooh 1000 used to be the Slooh 500 but it was expended when the new version of Slooh was released in June 2019.

What's also great about the Slooh 1000 is that there are Guides that tell you about the objects. The Guides are compiled from a variety of sources and go far beyond what's available to the public, including Wikipedia. You'll be able to learn about any of the objects in great detail with interesting facts. When you book a mission, the reservation confirmation screen takes you to the Guide for the object, so you don't even have to search for it to read the Guide. I walk you through this process in this chapter.

The Slooh 1000 list is integrated right into the reservation system, so it only takes a few clicks to end up with a reservation and a great photo.

The Slooh 1000 list doesn't change, however, what you can pick from the list changes based on what's visible in the sky. When you select a Slooh 1000 list reservation, Slooh calculates what's visible in the night sky and determines the best telescope to use, taking the guess work out of booking a mission. Using this list makes it easy to select a target even if you're not that familiar with the sky because only visible targets are available for you to select. This answers the big and most common question, "What's up in the sky tonight?"

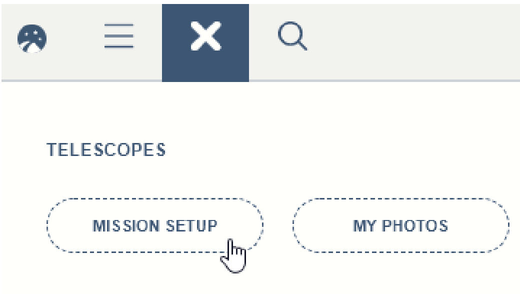
As a result, as you browse through the list, you'll see some entries are available to be selected whereas some are unavailable to be selected. The unavailable objects are not selectable because the object is not visible – perhaps due to the time of year, or perhaps because there aren't any available reservation slots to capture the best image.

Later in this chapter, we'll get into mission planning using KStars, the planetarium software you installed and configured earlier to book more advanced missions.

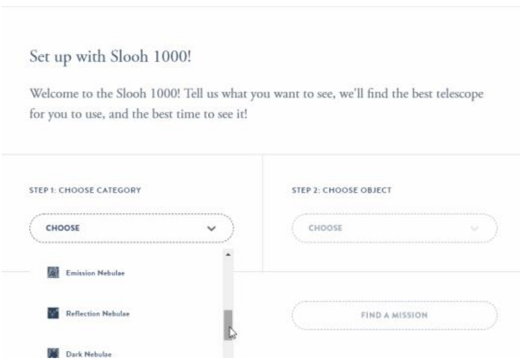
KStars takes the mystery out of mission planning and helps you take amazing photos regardless of the object you choose to view - it also opens up the sky beyond the Slooh 1000 list to many other things like comets, other galaxies, nebulas and even quasars over 8 billion light years away from us!

Let's get started and book a Slooh 1000 mission. I'm writing this chapter during the summer, so I'll walk you through booking a mission for the Andromeda Galaxy, which is visible at this time. You'll probably have to pick something else if you're reading this at another time – the steps remain the same even if the objects are different.

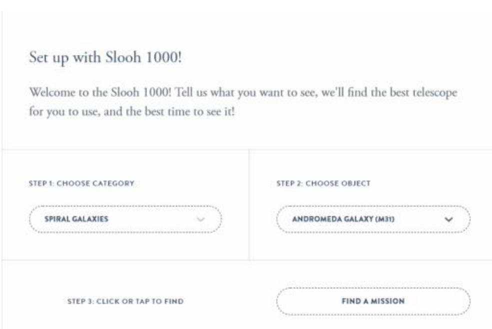
Start by logging in to Slooh and, from the top left of the screen, click the third icon from the left – the telescope icon. From there, click the Mission Setup button:



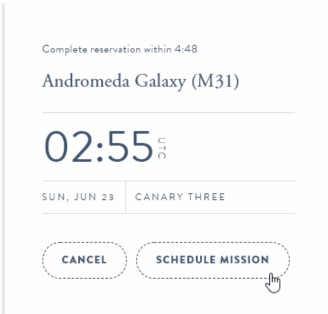
The “Mission Setup” button takes you right into booking a mission using the Slooh 1000 regardless of your membership level, making booking really simple. Click the arrow under “Step 1: Choose Category” to review the available types of objects:



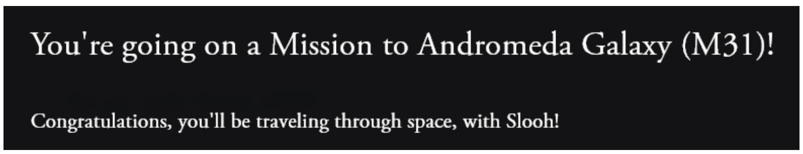
From the list, find and select the entry for Spiral Galaxies. Then, under “Step 2: Choose Object”, find and select the “Andromeda Galaxy”



Click the “Find A Mission” button to find an available telescope and reservation slot:



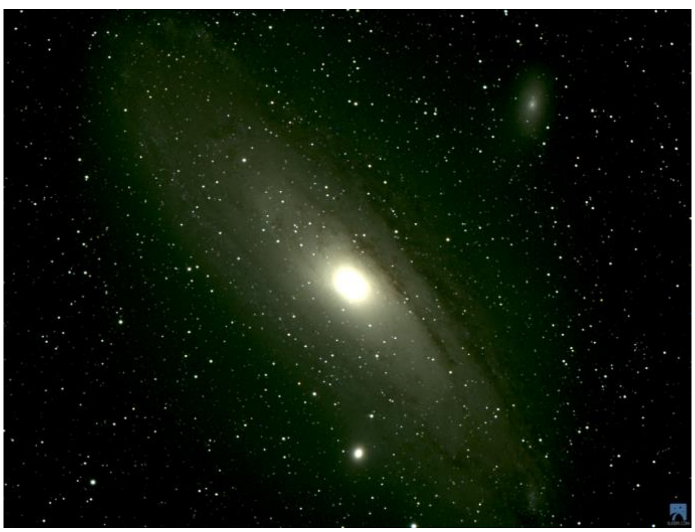
Click “Schedule Mission” to complete your reservation. You’re directed to a screen that shows you the following at the top:



This confirms your reservation.

Result of Booking a Slooh 1000 List Mission

Here’s the resulting image from the mission:



The image shows the Andromeda Galaxy at the center. The processing recipe tries to reach a good balance between the darker and lighter parts of the image and so has slightly over-exposed the center of the galaxy and very faint outer edges.

I explain later how to access the images you capture as a result of booking a mission in the chapter Viewing, Uploading and Downloading Images.

Missions Available to Members

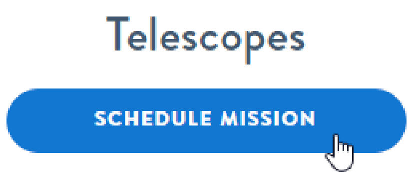
In this section, I describe how you can use the “By Catalog”, “By Constellation”, and “By Telescope” missions.

For now, let’s start by booking another mission for the Andromeda Galaxy using the “By Catalog” mission. The Andromeda Galaxy is also called Messier 31, so you’ll find it in the Messier catalog.

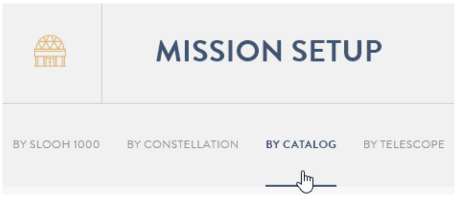
Booking A Mission By Catalog

Members can book missions using the “By Catalog” option. Apprentice members have four popular catalogs available to them – the four catalogs cover over 8,000 celestial objects. Individual Astronomer members have access to all available catalogs.

Start a new mission - from the top left of the screen, click the *Telescopes* icon and from there, click the *Schedule Mission* button:

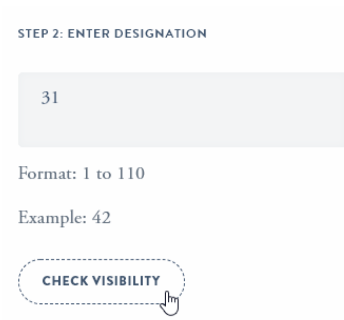


From there, select the “By Catalog” option as shown:



Locate the Messier catalog in the drop-down under “Step 1”:

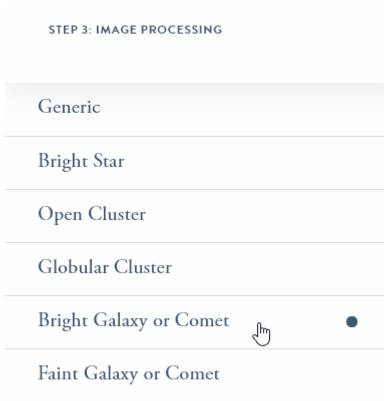
Under “Step 2”, enter the Andromeda Galaxy’s designation number, 31 and click “Check Visibility” as shown:



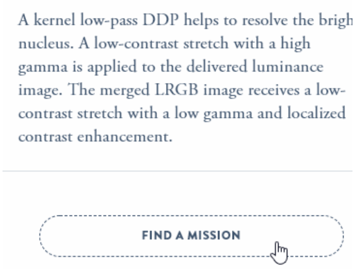
Slooh calculates the best time and telescope available for your observation:

Slooh indicates that Messier 31 is visible, as shown:

Under “Step 3”, you’ll find several options available for Image Processing. Click the various options to explore the processes available to you. I go into more detail about these options in the section called “Understanding Processing Options”. For now, select the “Bright Galaxy or Comet” option:


STEP 3: IMAGE PROCESSING
Generic
Bright Star
Open Cluster
Globular Cluster
Bright Galaxy or Comet
Faint Galaxy or Comet

When you select the Processing Option, the screen updates with a description of the option and makes available to you the "Find a Mission" button:



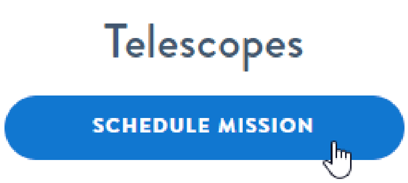
Click "Find a Mission" to find a telescope that supports your processing option and a time slot for the best viewing. Slooh presents you with the following to confirm your booking:

Click "Schedule" mission to schedule the telescope at the selected time. After you schedule the mission, you're directed to the Guide about Messier 31 and you can explore more about the object from there, as you did in the preceding section.

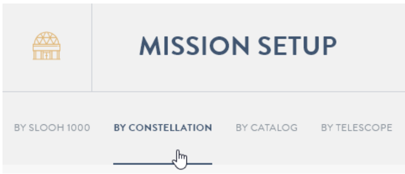
Booking A Mission By Constellation

Here I discuss the "By Constellation" option, followed by the "By Telescope" option.

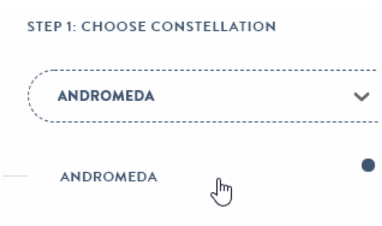
Start a new mission - from the top left of the screen, click the *Telescopes* icon and then click the *Schedule Mission* button:



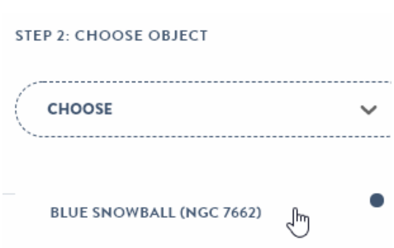
Select the “By Constellation” option as shown:



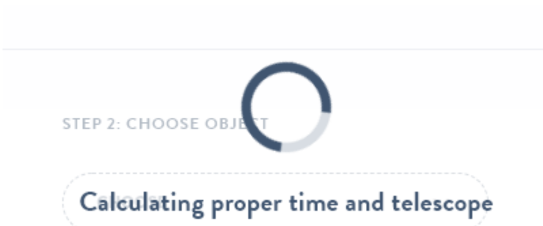
Choose Andromeda, or any other constellation that happens to be available to you when you’re booking the mission:



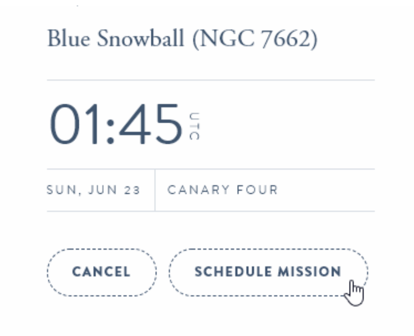
In this case, I’m selecting the Blue Snowball Nebula”



Slooh calculates the best time and telescope:



Slooh shows you the reservation details:



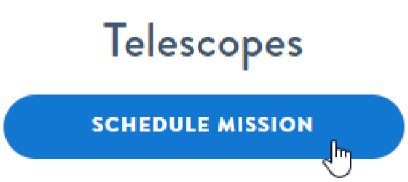
Click “Schedule Mission” to confirm the booking.

Booking A Mission By Telescope

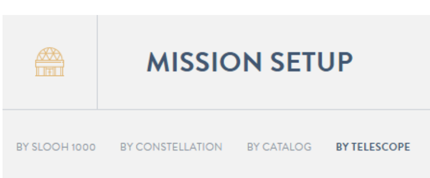
The telescopes at Slooh all have different capabilities and members can use the telescope best suited to their needs. Examples of capabilities are things like the fact that the telescopes each have different fields of view, another example is that some telescopes have better resolution which is good for objects that are close to one another, and yet another example is color capability – only one of the telescopes captures images in full color in a single shot. I discuss the Slooh telescopes in the section Understanding The Slooh Telescopes“.

In the next chapter I walk you through more advanced booking using the telescopes, but for now we’ll use the “By Telescope” mission to book a Catalog mission.

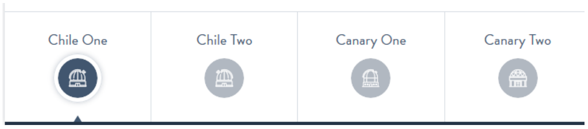
Start a new mission – click the *Telescopes* icon and from there, click the *Schedule Mission* button:



Click the “By Telescope” option:

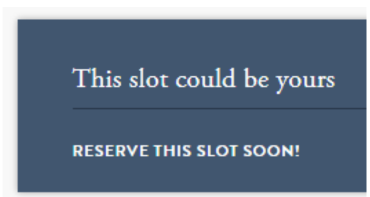


The screen changes to present you with a listing of telescopes and defaults to Chile One as shown:



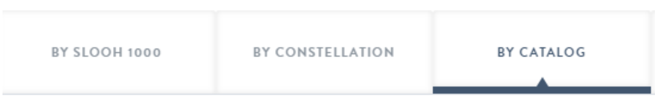
For now, select "Canary Two" and browse through available time slots. If the time slot you want is not available, select another night by going back to the top of the screen, and select the right arrow under the listing of telescopes to select the following night.

When you browse through the list of timeslots, available slots look similar to this:

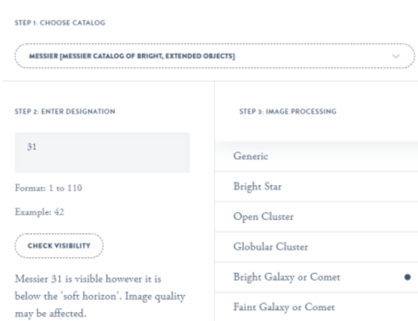


Andromeda is visible at around 2am UTC, so select a time slot around that time and select "Reserve This Slot Soon".

You're presented with options to book your mission – we'll use the "By Catalog" option for now:



Fill in the screen as shown in the following screenshot – I explain the options below:



Select Messier under the "Step 1" section and enter 31 in the "Step 2" field. Click "Check Visibility" to verify that the object is visible and select the "Bright Galaxy or Comet" processing option.

Click "Preview Mission" and then click "Schedule Mission" to complete the reservation. You're taken to the screen that shows you information about the object as you have seen in the "Understanding the Slooh 1000 List" section. Click "Finish" or "Go Back" to return to the listing of time slots for this telescope.

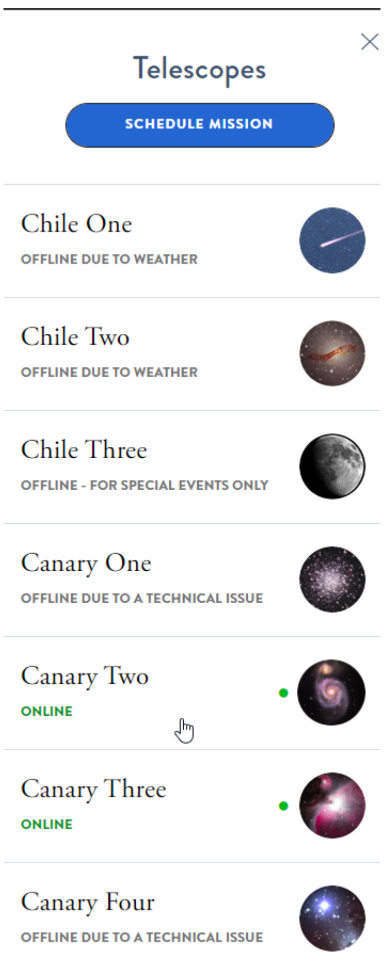
Individual Astronomer members can have up to five reservations at a time, so you can book another mission using the same or another telescope at this point. Family main and sub accounts and individual Apprentice members can have up to one reservation at a time.

Watching Missions Live

One of the nice features of Slooh is that you can watch missions as they are running as if you were sitting at the eyepiece of the telescope yourself.

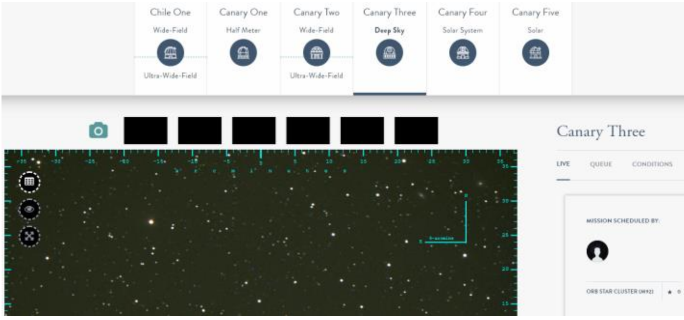
Watching missions live is a great feature because you can see the image on the telescope develop during the observation session. It's also nice when you want to gain insight into what others use the telescopes for.

Watching missions is a central feature of Slooh and you start by picking a telescope as shown:



A green dot next to the telescope indicates that it's online and available for viewing.

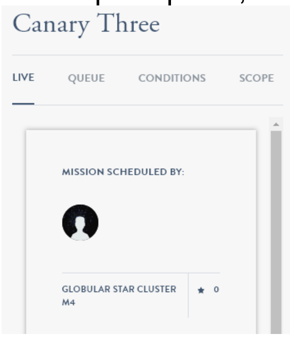
When you select a telescope, you'll see a screen similar to the following:



In this example, I'm looking at the Canary Three telescope observing Messier 92. The image is interactive – there are three icons on the left side of the image as shown:

Click the top icon toggles the scale shown at the edges of the image. The scale is in arcminutes and matches the telescope's field of view. The center icon toggles between a rectangular and circular view and the bottom icon toggles the full screen view; click "Go Back" at the top left to exit full screen view.

At the right side is packed with lots of information: details about the object you're looking at, the telescope's queue, information about the conditions, and information about the telescope itself:



The default view is the "Live" tab which shows you details about the object you're looking at if those details are available. Scroll down and you'll be able to enable the mission's audio, a great feature of Slooh. The mission audio tells you about the object as you watch; there are hundreds of recordings and they are very informative. Scroll a little more and view the object's Guide (click the arrow pointing to the right to view the Guide). A little further down you'll find the All Sky camera view too.

Click the "Queue" tab for messages from the Observatory Bot. This can include information about the current mission or missions that are coming up.

Click the “Conditions” tab for details about current conditions at the telescope. The view begins with messages from the Observatory Bot; scroll down using the inner scroll bar to view previous messages from the bot.

Using the outer scroll bar, scroll down to reveal the “All Sky” snapshot, followed by the Sky Conditions. The current weather conditions follow with details about the temperature, wind speed, and humidity. Further down are details about moonlight. Following that are details about the day/night bar and information about when the observatory opens and closes. The Dome and Peak webcam follow. The details are rounded out by a Weekly Forecast, Estimated Seeing Conditions, and a Satellite view of the telescope to help you gauge the weather conditions (this is only useful during the daytime).

Click the Scope tab for lots of information about the telescope itself, like messages from the Observatory Bot, and details about the scope in terms of its manufacturer, and open and closing times.

Across the top of the screen is the listing of telescopes - you can switch between available telescopes by clicking the telescope’s icon.

Just below the telescope view is a camera button with some empty slots next to it:

You can click the camera to take a picture of whatever is in the view of the telescope at the time.

Pictures you save here end up under the “Photo Roll” of the “My Photos” area. Refer to the chapter Viewing, Uploading and Downloading Images for details about how to access your images.

Next Steps

The next section describes how you can use Join missions to join others’ missions.

Understanding Joining Missions

One of the great features of Slooh is its community aspect - Slooh is all about sharing knowledge, images, and experiences and the Join feature directly supports that.

Browsing through reservations for a telescope, you might come across some interesting missions and wonder what the user is looking at. Here's an example:

The user, AlexanderS, has a coordinate mission scheduled and the description is "cosmic horseshoe". If you do some research in Clubs, you'll find that a number of members are imaging this object – it is a pair of very faint gravitationally lensed galaxies. The community project is attempting to capture a lot of images so that they can get a lot of exposure time to get a good final image of this object (I discuss long exposure times in the section Understanding Long Exposure Time).

It would be great if you could get an image of this object, but you don't have planetarium software to know where to point the telescope and when to schedule a mission. This is where the Join feature comes in.

The Join feature allows you to join a previously scheduled mission, just as if you reserved it on your own. You get the mission's images plus you get the FITS files from the mission too. FITS files allow you more freedom in processing and measurement and I discuss these files in the section called Understanding FITS Files.

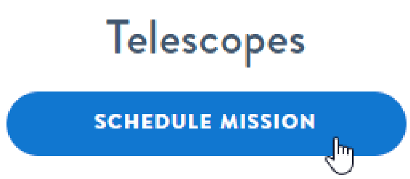
You have up to five Join missions at any time.

So why would you want to join someone else's mission? Here are some reasons:

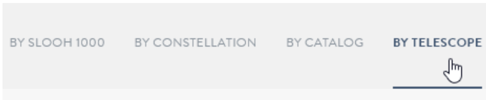
- You have used up your reservation limit, but you want more missions for a target and someone else happens to have a reservation for your target too
- Someone is imaging a difficult to capture object like an asteroid or comet, so you don't have to find out when it's visible or where it is – you just join the mission
- You're just curious about what others are imaging

Here's how you use the Join feature:

Click the *Telescopes* icon at top of your screen, and then click the *Schedule Mission* button:



From there, click “By Telescope”:

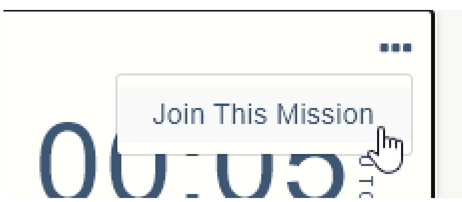


Select a telescope – in this case, I selected Canary Four:

Scroll through the reservations and find a slot that might be of interest to you.

Ensure that the slot does not say “This slot is no longer available” – this happens when the telescope is online and missions have already run, or are about to run.

Find an available mission and click the three dots next to the time, as shown:



Click “Join Mission”:

Click “Schedule Mission” to confirm the mission:

Slooh responds with the following message, indicating that the reservation is confirmed:

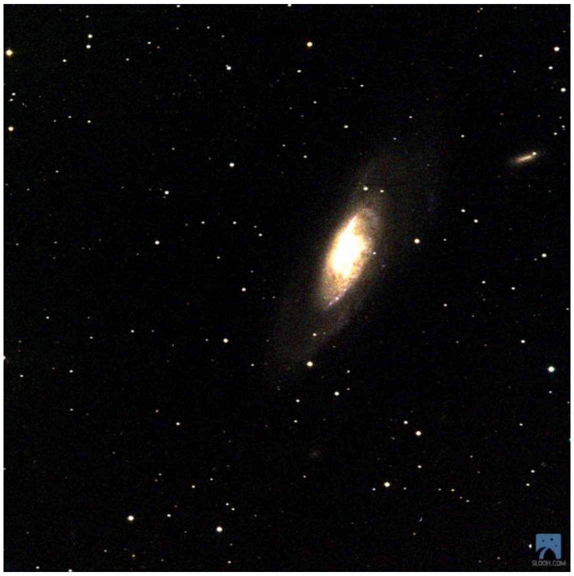
You’ll get an email, usually the next day, indicating whether your mission ran. If it was successful, you can go to the “My Photos” to check your images. I discuss “My Photos” in Viewing, Uploading and Downloading Images.

Next Steps

The next section discusses Processing Options and how they affect your images.

Understanding Processing Options

When you select one of the images that Slooh produces, you end up with something like this (in this case the image of NGC 4258):



Although there are four images of this object in the “My Photos” area, this one is a combined image that has been processed using the Faint Galaxy Processing Option.

Let’s step back a little: I mentioned that the image is combined, but combined from what? I explain in Understanding The Filters Slooh Uses that the telescopes actually take images in black and white and use filters for you to be able to create a color image. The preceding image was created by combining images using the other filters – refer to Understanding The Filters Slooh Uses for more details about filter and color.

I also mentioned a “Processing Option”. The “Processing Option” affects how your images look and this option is either selected for you (like when you book a Slooh 1000 List mission), or something that you select.

This section goes into detail about Processing Options and how to select a suitable option.

Deteails About Processing Options

Slooh supports several ‘Processing Options’, all of which affect the resulting image you get in your “My Photos” area.

If you’re an individual Apprentice or Astronomer member, and you book something other than a Slooh 1000 List mission, you have the option of selecting the Processing Option.

There are currently eleven Processing Options - the table below lists the available options along with Slooh’s and my comments:

Processing Option Name	Slooh’s Description	Comment
Generic	A low contrast linear stretch is applied to both the delivered luminance image and the merged LRGB image.	The values of the pixels in the image are modified resulting in low contrast. The modifications are made to the Luminance image (clear filter) and combined LRGB image. This attempts to control midtones, shadows, and highlights.
Bright Star	A low contrast stretch with a high gamma is applied to darken the sky background.	The values of all the pixels are evened out so that the contrast is relatively low and the brighter and darker areas are highlighted, providing a contrast between the dark sky and bright stars.
Open cluster	A low contrast linear stretch is applied to both the delivered luminance image and the merged LRGB image.	Open clusters are a sparse grouping of stars so the process lowers contrast on the luminance/clear filter image and applies the same to the combined LRGB image.
Globular cluster	An FFT based DDP algorithm is applied to aid in resolving both the cluster center and edges. After DDP, a high gamma stretch is used with parameters similar to those used for the Moon.	A specialized process evens out the image so that the midtones are more visible without losing the details in the shadows and highlights. The gamma stretch reduces contrast for brighter areas of the image making the center of the globular cluster more visible.
Bright Galaxy or Comet	A kernel low-pass DDP helps to resolve the bright nucleus. A low-contrast stretch with a high gamma is applied to the delivered luminance image. The merged LRGB image receives a low-contrast stretch with a	A specialized process tries to make the image such that the usually bright nucleus of the comet or center of the galaxy is not over-exposed while still retaining detail in the midtones and shadows.

	low gamma and localized contrast enhancement.	
Faint Galaxy or Comet	A medium contrast stretch with a low gamma is applied to pull out faint details.	The values of the pixels are modified such that the contrast is low but still retains details in the areas with little contrast (faint areas).
Large Bright Nebula	A low contrast, low gamma stretch is applied to the luminance images. After color merging, a high gamma stretch is used. This recipe assumes there is little to no dark background sky in the image.	This option attempts to brighten most of the image by processing the luminance and color images separately. This option assumes the nebula takes up almost all of the available image so the process evens out the values of the pixels in the image, overall making it brighter.
Small bright nebula	A low gamma Moon stretch is applied to the luminance images. After color merging, a linear stretch is used. This preset is designed mainly for planetary nebulae.	A process whereby the brighter areas are reduced so that they're not over-exposed while still keeping details in mid-tones and shadows.
Faint nebula	A medium contrast stretch with low gamma is applied.	Enhances faint parts of the image (those where the contrast is low) and enhances details
Multi Luminance 20-secs*	Multiple 20-second exposures using the Luminance filter at 3x3 binning. Of most use when tracking fast moving objects such as Near-Earth Asteroids.	Several exposures were taken with the luminance/clear filter only. This results in a black and white image that's often used to image near earth asteroids and other faint objects. This option is available only to individual Astronomer members.
Multi Luminance 50-secs*	Multiple 50-second exposures using the Luminance filter at 2x2 binning. Of most use for scientific measurement or astrophotography.	Several exposures taken with the luminance/clear filter only. This results in a black and white image that's often used to image faint objects or used for scientific measurements. This option is available only to individual Astronomer members.

All of this seems pretty involved and Slooh hides a lot of this through the Slooh 1000 List. However, the ability to choose the processing option is very powerful and can really improve the images you get from Slooh. For an example of how dramatic the changes can be, refer to the following Wikipedia article that shows just what gamma correction does (see the image on the right side of the page). As you have seen from the preceding table, Slooh does more than just gamma correct the image, so the results can be quite striking. Here's the link the Wikipedia article on gamma correction: https://en.wikipedia.org/wiki/Gamma_correction

One thing to note is that the Processing Option does not affect the FITS files you get from Slooh. The FITS files are only calibrated, regardless of what Processing Option you choose. I discuss what FITS files are and what calibration is about in the section called Understanding FITS Files.

I put an asterisk next to the Multi-Luminance processing options to highlight a difference with these processing options:

- Multi-Luminance images are black and white images that only use the Luminance filter. Refer to the section called Understanding The Filters Slooh Uses for information about filters.
- Multi-Luminance images are primarily of interest to those trying to image faint objects, or for scientific use, or to enhance their astrophotography images by stacking FITS files. Refer to the section called Understanding Stacking and Multi Luminance Processing for details.
- These options are not available on telescopes with a one-shot color camera (as of publication, only Canary Three uses this type of camera).
- Canary Four only supports the Multi-Luminance 50 option.
- The number of resulting FITS files varies based on the telescope (you get more FITS files from Canary One because it has a longer exposure time), and the time available for the mission. Sometimes the telescope doesn't have enough time to collect all of the luminance images because the slew from the previous target took a long time.

So the question is, given all of the options which Option do you use? The answer is: it depends on the subject you're imaging and what you plan to use the image for – the next section discusses this.

Picking a Suitable Processing Option

From the description of each Processing Option, you can see that which one you select depends on the type of object you're imaging, and Slooh has done a good job at making available Processing Options that are suitable for a broad range of objects. For example, Slooh even distinguishes between small bright nebulae and large bright nebulae, which is great.

So the Processing Option requires that you have prior knowledge of the object you're imaging. But where do you get information about the object you're about to image in order to know which Processing Option to use?

You could start by using your favorite search engine to search for an image of the object to get an idea of what you're imaging. Be aware that most of the images you see online were taken by the Hubble Space Telescope, were taken by some sky survey using a very powerful telescope, or were taken using some very advanced equipment with heavy post-processing involved. As a result, the image you get from Slooh is going to be quite different. For example, search for images of the Eagle Nebula and then take an image of the same nebula using Slooh – there's a huge difference between them due to the reasons I just mentioned.

If you're imaging an object on the Slooh 1000 List, you can search for it at Slooh and to find Observations other members have shared in the past (refer to the section called Exploring the My Observations Tab). You'll get a good idea about how the object will look in the Slooh telescope.

Another good resource for images is KStars, which we used in the Mission Planning and Booking section. KStars gets its images from the Sloan Digital Sky Survey which uses a very large telescope. The sky survey covers about 35% of the visible sky but there's a good chance your target will have an image for it.

Another good resource is a Google image search at https://images.google.com. Enter the name of the object you're searching for, keeping in mind that you'll likely come across some incredible images. I'm not saying images like that are not possible using Slooh, I am however saying that you need to understand that Slooh takes a few minutes of exposure compared to hours of exposure in photos you find online.

A great place to search for amateur images is Astrobin.com (https://www.astrobin.com/). It's a community site by astronomers, for astronomers. You can not only search by the name of the object, you can also search by a whole variety of factors including cameras, telescopes, integration time, software used, locations, and a range of other factors. You'll find all sorts of details about images including the telescope, camera, software used, integration time, images are also annotated to make it easier to figure out where to find the object in the sky.

Yet another great source of images is Aladin at https://aladin.u-strasbg.fr/. The advantage of Aladdin is that it uses a number of sky surveys so chances are high that your object will be available. There are two versions of Aladdin - a downloadable version you run on your desktop computer and a lite version that runs in your browser. The browser-based version is probably good enough for just looking up images, however the downloadable version allows you to do more. I discuss Aladin in several articles on this book's companion website RemoteAstrophotography.com.

Once you have an image of the object you're looking for, consider the differences between the brighter and darker areas of the image. For example, consider the Eskimo Nebula (NGC 2392):

This image is from Slooh and uses the Generic processing Option. The image contains bright stars and the relatively bright and small nebula just below the bright star in the center of the image. While you do indeed have a photo of the nebula, you are missing out on the fainter details.

Here's a zoomed-in image of the nebula from Wikipedia:

(Image credit: https://en.wikipedia.org/wiki/Eskimo_Nebula)

This image was taken using a 32 inch telescope, which is much larger than Slooh's largest telescope, Canary One. In addition, it looks like the exposure time was quite long to capture the detail in the nebula. It does, however, give you an idea of the details that could be visible with the right processing and acquisition.

Here’s an image of the same nebula I took using Slooh:

This image is based on three missions and was processed using various software tools including MaxIM DL and Photoshop. Although it is a little over-processed, the difference is significant in that you can resolve the fainter aspects of the nebula, the core is not overexposed and the stars are not as bright as in the image from processed using the Generic option from Slooh.

I mentioned that selecting the Processing Option depends on two things – the target you’re imaging and what you plan to use the image for. We have discussed the target so now I’ll briefly discuss the other aspect: the image’s purpose.

In the preceding section, I showed you a large table listing all of the Processing Options. Except for the multi-luminance options, the remaining options are primarily used for astrophotography, meaning, that the images are intended to be used for sharing with others and so have lots of color information in them along with advanced processing. They result in nice images, however, they’re of little scientific use.

The multi-luminance processing options provide users with FITS files that have the most data about the target possible and with no advanced processing. As a result, these images are of better quality for scientific use – specifically the FITS files are of interest, not the black and white images. I discuss FITS files and their use in the section called Understanding FITS Files.

Picking the right processing option is as much art as science and I encourage you to try different processing options with the same target. Also try different telescopes since there are differences between the telescopes’ capabilities in terms of image size, resolution, and exposure time.

Next Steps

Now that you understand the images Slooh produces for you and have seen what else is possible, it’s time to explore the other files Slooh produces for you: FITS files. FITS files contain a great deal of information and are very useful not only for producing better images, they’re also useful for doing things like scientific measurements and reporting observations to governing bodies like MPC.

Using KStars to Plan and Schedule a Mission

I remember in 2014 when I signed up for Slooh initially, I was always taking photos of the same objects and didn't really have a good understanding about what was available to me for imaging. At the time, Slooh didn't have the Slooh 1000 List so it was difficult to find out what objects were visible in the sky. In addition the photos I took all looked the same and I didn't really know what to do with them. It became frustrating and I actually stopped taking photos for a few months. During that time, though, I kept on reading and researching and eventually found planetarium software.

Planetarium software is an application that astronomers use to plan observations, do research, verify photos they have taken, log their observations, and even control the camera and telescope (although you won't need those last two features when working with Slooh). Planetarium software contains a database of stars, planets, comets, asteroids, and even satellites. Using the database and some incredible math, the software makes it possible to figure out what's up in the sky on any given night from your location. The software is also interactive in that it shows you what the night sky looks like at any time so it also helps you compose your images before you see them, so there's a lot less guesswork involved in setting up a mission.

When you have the Slooh 1000 List, why would you need planetarium software? Planetarium software's strength lies in its database. Many planetarium software packages include databases that contain millions of stars, which is great when you want to research variable or multiple star systems, the databases contain a million deep sky objects, high quality images of many objects, satellite tracking, import of comet and asteroid databases, and the ability to query those databases based on your interests and observing plan. In addition, planetarium software helps you plan observations, sometimes months in advance, you can plan mosaics (taking images of large areas of the sky that go beyond the telescope's capability), you can find conjunctions between various objects, and there are many more features.

While I don't use KStars to book missions myself, I use TheSkyX, I found it to be great for scheduling and planning missions. I use TheSkyX because I like to research uncommon objects and I find its features more suitable for what I do. Plus, TheSkyX comes with support and updates so when I run into issues I can get that addressed relatively quickly.

The sky database is central to any planetarium software and KStars does a good job of using publicly available databases for its sky map. I find that since I like to view unusual objects, TheSkyX offers databases that aren't readily available in other planetarium software. While I can certainly get much of the information I need online, there's nothing quite like working in a single application to get everything done in one place.

Let's jump into using KStars to plan and book a mission.

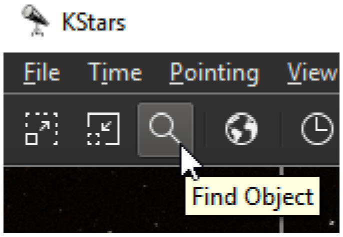
I'm writing this book during the winter, so the object I'm going to plan to view is Messier 42, the Orion Nebula. If that's not available to you when you're reading this, try something like the Dumbbell Nebula (Messier 27) during the summer, the Beehive Cluster (Messier 44) during the spring, or Bode's Galaxy (Messier 81) during the fall. While you'll find these objects in the Slooh 1000 List, the purpose of this exercise is to get you familiar with using KStars.

Let’s start by opening KStars - click the Start menu on your system, start typing KStars, and select KStars Desktop Planetarium from the menu.

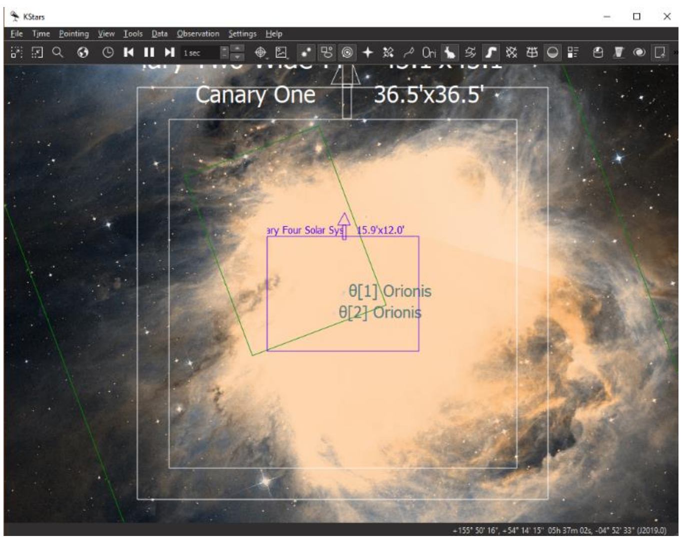
When KStars starts, it’ll use the location you configured in the Software Setup chapter. This is really important because the sky looks different based on your observation location. KStars uses your system date and time initially, so you’ll see the sky as it appears right now. You can change the date and time to thousands of years past and future.

Before you do anything else, make sure that the Canary Islands is set as your location. Select Settings - Geographic and make sure that the location we configured earlier, Observatorio del Teide, is still set. If you didn’t set it up, go to the chapter on Software Installation and Configuration and follow the directions there for KStars.

Click the Find Object button on the toolbar:



Type “M 42” (without the quotes) and hit enter. Your screen should look something like this:



If all you see is a black sky with some squares on it, there could be one of two issues:

- The image is taking some time to download, so you might have to wait a minute for it to show up
- You have not configured KStars to get images from the internet. It’s a simple fix: select View - HiPS All Sky Overlay - DSS Colored

So what are we looking at?

The big bright area in the middle of your screen is a photo of M 42 downloaded from the DSS sky survey data. The DSS is short for the Sloan Digital Sky Survey, a series of photos taken of about 35% of the sky using a powerful telescope. The photos are available online for anyone to use and they make it possible for applications like KStars to integrate the photos, making them more readily available to you.

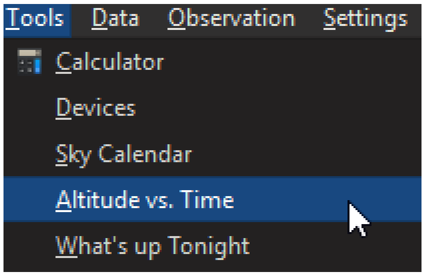
The green boxes are the boundaries and are not of interest to us at this time. The white boxes are the field of view indicators for the various telescopes. If you don’t see the white boxes, go to the chapter on Software Installation and Configuration and follow the directions there for KStars setup.

Use your mouse wheel to zoom in and out so you can see all four of the field of view indicators. Based on that view, to capture the whole nebula in a field of view, you would need to use the Canary Three telescope. The Canary Two would also be a good alternative. The view from Canary One would be too narrow to capture the nebula, but you'd still capture a good photo using it.

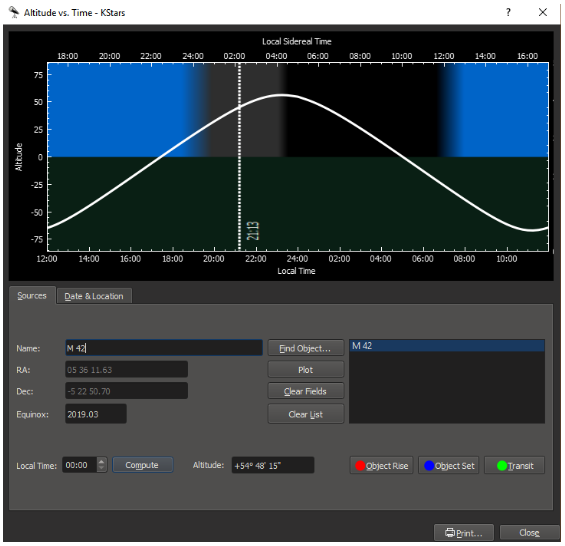
So now we know what telescope we want to reserve and what our image is likely to look like, so that already has taken a lot of guessing out of the process of planning a mission, and all we've done so far is searched for M 42!

So now we have to figure out when the best time will be to view M 42.

In KStars, select Tools - Altitude vs Time, as shown:



In the Name field, enter M 42 and hit enter. On the right side of the box, make sure M 42 is selected and your screen looks something like this:



If you're following along but using another object your display will look different, but the same principles apply.

The graph shows two interesting bits of information - along the left is the altitude above and below the horizon and along the bottom is the time. The white and curved line shows M 42's progression across the sky for 12 hours. The blue bands on the left and right represent the daytime when M 42 won't be visible at all.

The curved line indicates that M 42 will be at its highest point in the sky at about midnight, at which point it will be about 56 degrees up - this is the ideal viewing time, based on the date we have selected. This time where M 42, or any object for that matter, reaches its highest point is called the Transit Time.

The Transit Time happens when an object reaches the meridian, or the imaginary central line running through the earth's meridian - an imaginary line that runs through the north and south poles. That's the technical description.

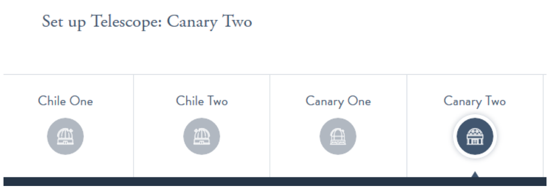
So why is the transit time so important? It's because that's when an object is at its highest point in its march across the sky and there's the least amount of atmosphere between the telescope and the object, making for great conditions to view the object. Depending on how picky you are, you might not want to image something during its transit. For big and bright objects like M 42 the difference is very minor, but the transit time plays a big role when imaging faint objects like asteroids, dark nebulae, and quasars.

Due to how the Slooh telescopes are physically set up, we cannot view objects within half an hour of their transit time. This means, in this case, we cannot book a mission between 11:30 pm and 12:30 am for M 42 on the selected date. Unfortunately, there's no getting around that restriction but it helps in the planning process. In case you try to book a mission during an object's transit, Slooh will warn you and not allow you to book the mission.

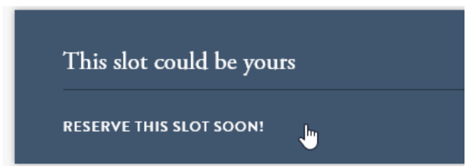
So now we know when M 42 is visible, we know which telescope we're going to use, and we know how the image is going to look when we get it. Let's book the mission.

Keep KStars open since we may need to refer to it when we're booking the mission.

We decided to use Canary Two so find that telescope and start booking a mission. Select the telescope at the upper left of your screen , click the "Mission Setup" button and select "By Telescope". From there, select Canary Two as shown:



Start by checking if the time you want to book the mission is available. I selected around 1 am - after the transit time.



I don't want to book too long after the transit time for the best photo, so if there's not a slot available between, say, 1 am and 2 am, I'll use the next day.

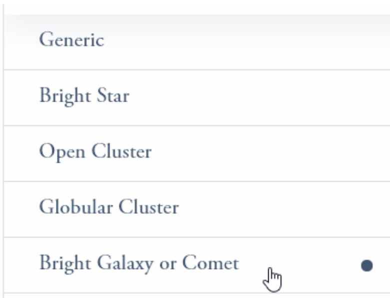
If I need to change dates, I'll recheck M 42 in KStars to make sure that my time is still good. Go back to KStars, and select the Date and Location tab. Pick your date on the calendar and click the Update button at the bottom right side of the box to update the view. Make sure the transit time is roughly the same - and it should be since it doesn't vary much between successive nights.

Select the "Reserve This Slot Soon" option from a time slot around 1am and then select the "By Catalog" option as shown:

Select the Messier catalog under "Step 1" as shown:

Under “Step 2”, enter the designation, 42, and click “Check Visibility” as shown:

From there, the screen updates indicating that the object is visible and presents you with various processing options. Select the “Bright Galaxy or Comet” option as shown:

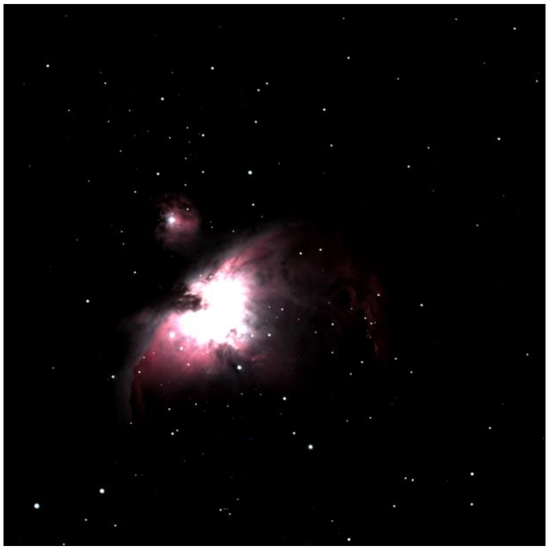


The screen will update again, showing you the details of the reservation:

Click “Schedule Mission” to complete your reservation. From there you can click “Finish” or “Go back” to return to the listing of reservations for this telescope.

Result of Using KStars to Plan and Schedule a Mission

The following is the result of the mission:



Our photo looks a little different from the one in KStars because the KStars image was over-exposed quite a bit and showed a lot of the surrounding nebula. While this image also captures those details, they're not apparent here because the "Bright Galaxy or Comet" processing recipe tries to reach a balance between the darker and lighter parts of the image. Some processing would lead to a better result, but this is a very good result.

Next Steps

Great! Now we have one more reservation to try - a coordinate mission!

Coordinate missions are typically used by advanced users to point the telescope at an exact point in the sky when hunting things like comets, asteroids, or even satellites. Coordinate missions are also helpful when you want to compose your shot to make the best use of the telescope's field of view. That's the subject of the next section.

Planning and Booking a Coordinate Mission

As I mentioned earlier, coordinate missions are typically used by advanced users to point the telescope at an exact point in the sky when hunting things like comets, asteroids, or even satellites. Coordinate missions are available only to main Family accounts and individual Apprentice and Astronomer members.

I discovered the use of a coordinate mission when I realized I didn't want whatever I was looking at to be at the very center of view of the telescope's field of view. Sometimes there are a couple of galaxies close together, so rather than taking two photos, I might be able to capture both in one photo. In other cases, like with M 42, there might be particular regions I want to look at more closely while still focused on M 42 - I just don't want the main part of the nebula in the field of view. Now I use coordinate missions to image objects like comets that are not on the Slooh 1000 List, asteroids, and other objects that are not on the Slooh 1000 list.

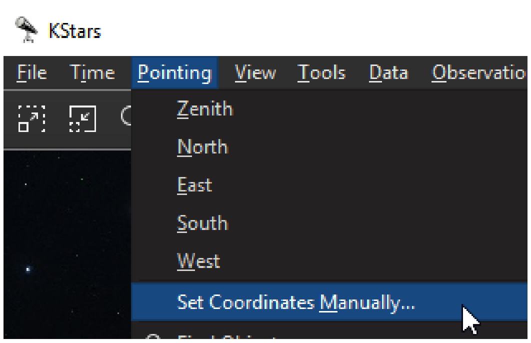
Markarian's Chain is a group of eight galaxies that reside in the Virgo Cluster - another grouping of about 1,300 member galaxies. Markarian's Chain is a beautiful cluster and needs a telescope with a wide field of view to be able to capture all of it. In this section, I'll walk you through planning a mission to this chain of galaxies and compose a good shot of it. I also show you the result.

Since I'm writing this in the winter, Markarian's Chain is visible, but it might not be when you're reading this. The same principles apply, regardless of the object you're viewing, so feel free to follow along, even if you can't actually make the reservation - I include the result of this reservation so you get the complete picture here.

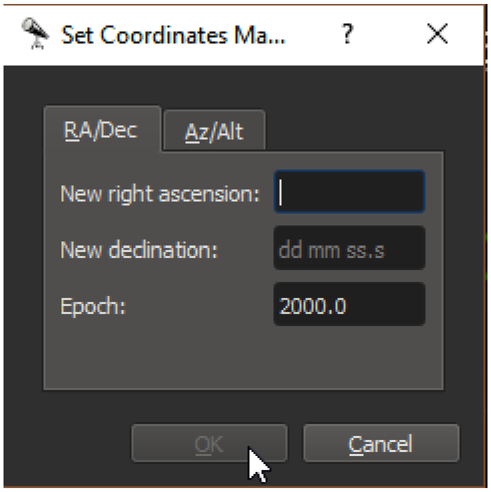
Although we can find Markarian's Chain using one of its member galaxies, like M 84, another way to view it in KStars is to enter its coordinates directly.

So how do we find the coordinates? Wikipedia to the rescue! Open Chrome and go to Wikipedia (https://en.wikipedia.org). In the search box, enter Markarian's Chain and go to the first result. Just under the picture of the chain on the right, is a box that lists the constellation and its coordinates - the Right Ascension and Declination. The coordinates are analogous to latitude and longitude here on earth: it's a way to find an object precisely.

In KStars, select "Pointing" – "Set Coordinates Manually", as shown:



Click the “RA/Dec” tab to reveal the “Set Coordinates” box:

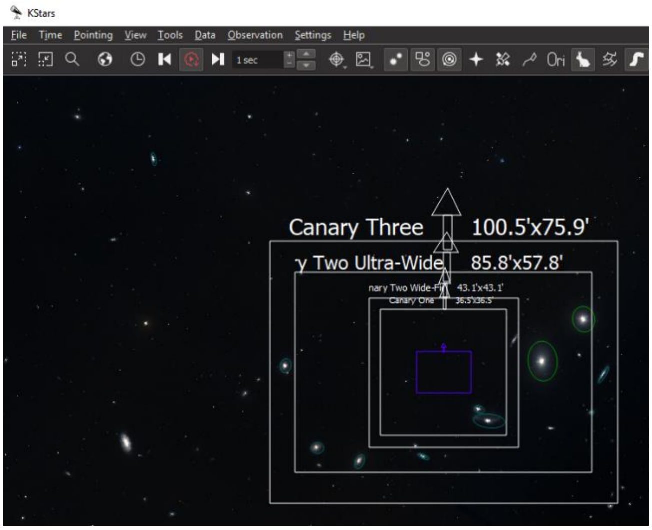


One thing that jumps out at me right away is that there’s a difference between the coordinates Wikipedia gives me and the ones KStars wants me to enter. You’ll notice that the ‘New declination’ box has dd mm ss superimposed on it, so it’s asking for three numbers. The Wikipedia page gives only two numbers for declination and it’s marked with degrees and seconds, so what’s going on?

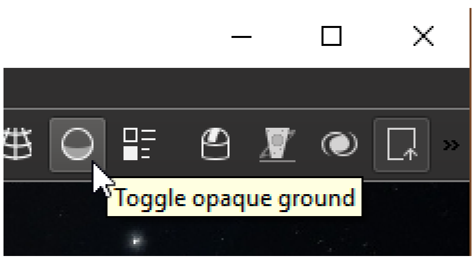
Right Ascension (RA) and Declination (Dec) can be written in many different ways and there are conversions between the different methods. A lot of the differences have to do with tradition and others have to do with precision. While RA and Dec can pinpoint a location in the sky, sometimes that high level of detail is not necessary because, in this case, the object we want to view is quite large, so all three numbers are not needed. In this case, the last number is assumed to be zero (00) and is good enough to be able to view the object.

So, let’s type “12 27” (without the quotes) into the “New right ascension” box, and “13 10” in the “New declination” box, and leave the Epoch at 2000.0. Click Ok to get KStars to change the view.

If Markarian's Chain is below the horizon, KStars will warn you, and you can simply accept the warning message since it doesn't affect us. Your display should look something like this now:

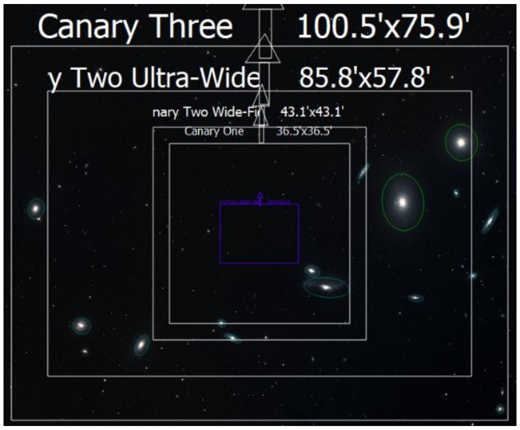


If you see only a black sky, chances are that KStars is looking at the ground, so you may have to disable it. Click the 'Toggle opaque ground' option on the toolbar as shown (it's the sixth icon from the right):



So now we have Markarian's Chain in view. Use your mouse to drag around the view to find a telescope that will capture all of the members of the chain and place that view so that it's nice to look at. I positioned the galaxies so that they're not too close to the bottom edge of Canary Three and also centered in the view.

My screen looks like this:

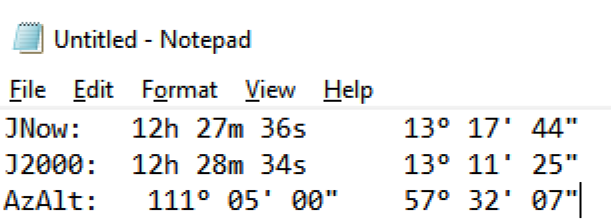


Now we know that we're going to use Canary Three, so now we need to capture the coordinates of the center point of our view so that the telescope can point at it.

Put your mouse pointer at the center of the Canary Four square, right-click, and select 'Copy Coordinates', as shown:

KStars copies the coordinates to your clipboard, so before we do anything else let's save those coordinates. Click your Start menu, start typing "Notepad", and click the Notepad application when it comes up.

On your keyboard, press CTRL + V to paste the coordinates - your screen should look something like this (don't worry if the numbers don't match exactly):



The numbers we're interested in are on the second row, J2000. The first number, 12 h 28m 34s is the Right Ascension and the second number, 13° 11' 25" is the Declination. Leave Notepad open for now and let's switch back to KStars.

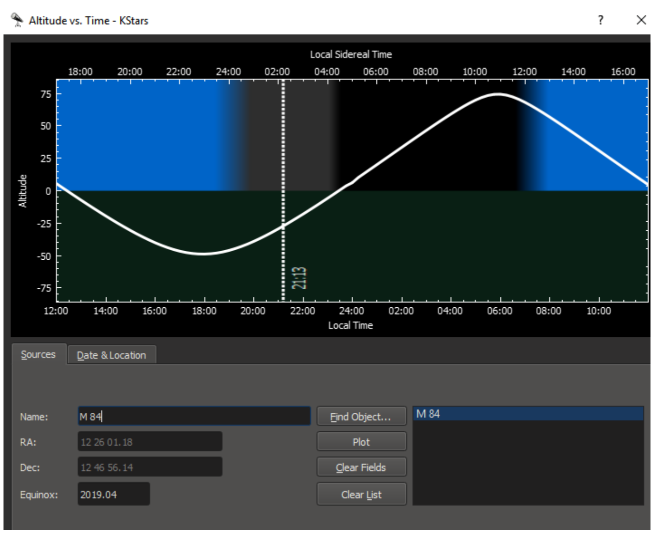
The next thing we need to do is figure out when it's going to be in the sky. KStars is a little limited in that it doesn't tell you when a particular point in the sky is going to be visible. More advanced planetarium software like TheSkyX can do that for you – you can click any point in the sky and TheSkyX will tell you the transit time and other details to help you figure out if that point will be visible.

KStars needs an object to derive its position at which point it will be able to tell you when the object will be visible in the sky. Since Markarian's Chain is so big we can use one of its member galaxies to derive when the cluster will be in view.

Let's search for one of the members, M 84 using the Altitude vs Time dialog to get an idea about when to book a mission.

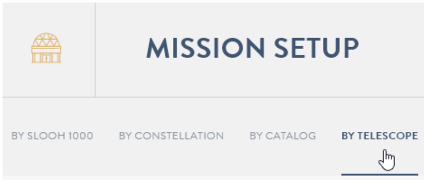
1. Select Tools - Altitude vs Time
2. Click the Clear List button
3. Enter M 84 in the Name field and press enter

Your screen will look something like this:

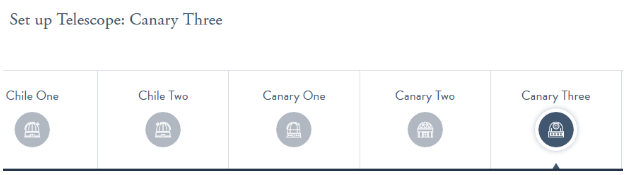


From this we can see that the transit occurs at around 6:00 am, so we'll probably be booking a mission near the end of the night. Keep this window open for now and login to Slooh.

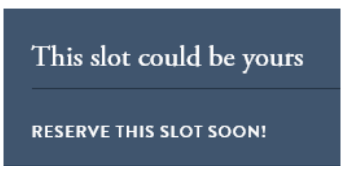
In Slooh, click the *Telescopes* icon and from there click the *Schedule Mission* button, then select the "By Telescope" option as shown:



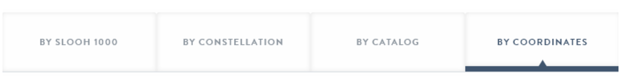
Select the Canary Three telescope as shown:



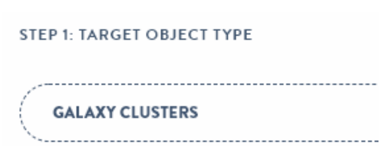
Look through the schedule and find whether a time slot around 05:00 UTC is available. If not, try another day and check in KStars. Keep in mind that the transit does not change by much on subsequent days, so if you assume a transit time of 06:00 you'll probably be ok. Once you have found a time slot, click the option labeled "Reserve This Slot Soon", as shown:



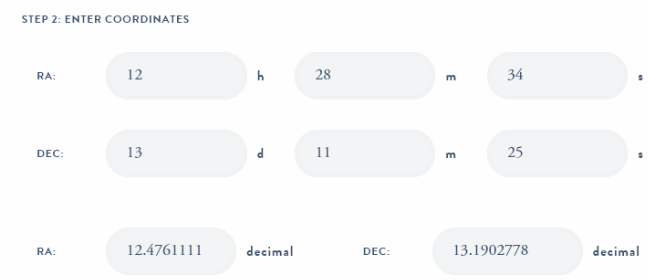
The Mission Setup interface comes up, so begin by clicking the "By Coordinates" option:



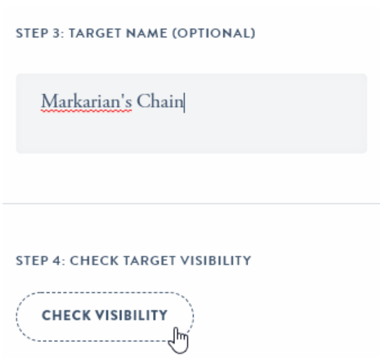
In "Step 1" select the "Galaxy Clusters" option as shown:



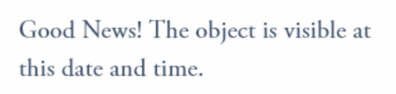
Now enter the coordinates on the second row of Notepad. As you enter the coordinates the decimal version of the coordinate will update. You can actually enter coordinates in either format (hours or decimal):



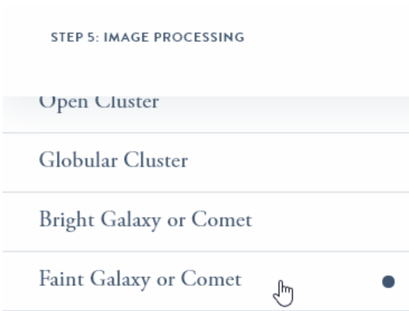
Also enter the name of the target as shown and then click “Check Visibility” as shown:



Of course, Slooh agrees that the coordinates are visible and shows you the processing options.



The chain is actually rather faint, so I selected the Faint Galaxy or Comet processing option:



I explain Processing Options in the section Understanding Processing Options.

You're shown the booking confirmation screen at this point and you can go back to the telescope reservations by clicking "Go Back" or "Finish".

Result of Booking a Coordinate Mission

I captured the result of the mission here for you:

As I mentioned when we were making the reservation, some of the galaxies are rather faint and the grouping is quite large, so it doesn't quite look like what we saw in KStars. Remember that the telescope used to capture images you see in KStars is about 250 cm wide so it captures much more light. The Canary Three telescope is 30cm wide, but this is still a great result from a single mission.

Compared to what we saw in KStars, the results don't quite line up - I think the whole shot is moved slightly to the right. This is probably happening because there was some maintenance work going on at Slooh while I was writing this and there were some corrections being made to the pointing of the telescope.

The fact remains though, we got a good image with no guesswork at all using KStars.

Next Steps

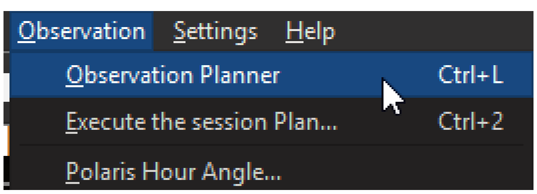
Now you know how to make reservations using the Slooh 1000 List and can use KStars to plan both a catalog and coordinate mission.

The next step is to further expand your horizons to include the entire night sky instead of just a few objects. We'll use KStars to plan to observe some different objects.

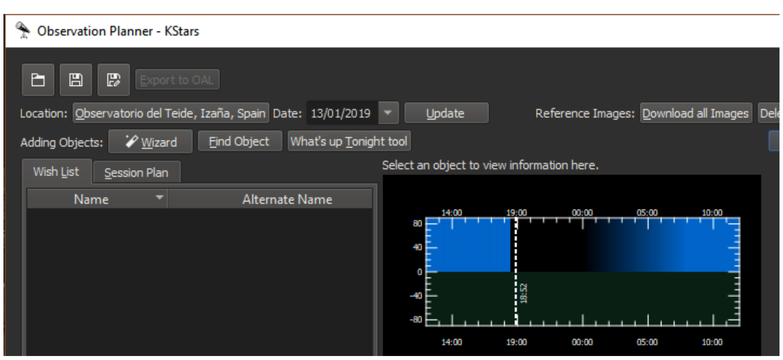
Using the KStars Observation Planner

So far you've used KStars for looking up objects of interest and composing shots. Now we're going to use KStars to plan our observations using just about everything available in the sky.

Start KStars and select Observation - Observation Planner as shown:



The Observation Planner window comes up:



There are a number of elements of interest here. The most important thing about this window is that it allows you to navigate around the KStars main window while it is open. This is important because you can center objects to view, zoom in and out and do other things while this window is open - you'll soon see that this is a very handy feature.

What this window does is help you create and manage an observing plan which is basically a list of objects you want to observe.

Across the top are three icons where you can open and save an observing plan - this comes in handy for cases where you're planning in the distant future and want to save observation plans for a later date.

Next is the location and date - both key data points since both affect what's available for us to view.

Below that are three buttons:

- Wizard - we'll use this to populate our observation plan
- Find Object - we have used this window before to find M 42
- What's up Tonight Tool - I'll walk you through this later in the chapter; however, I find the Wizard much more useful for casual observing

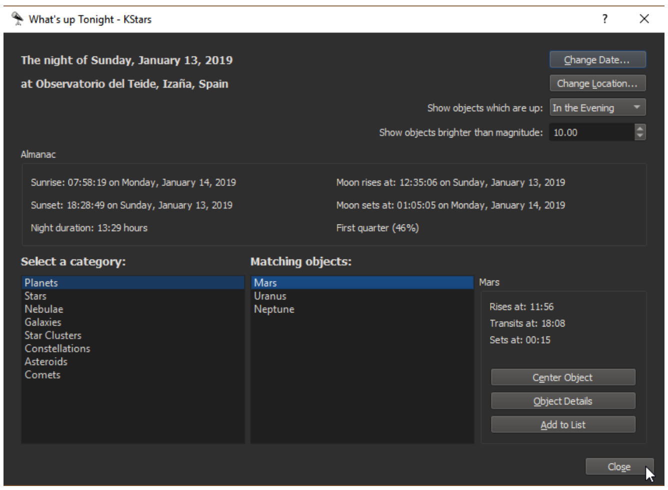
The large box below those buttons lists targets in your observing plan, separated into a wish list and session plan. I don't use Session Plans - I find they're useful if you have your own telescope and plan to target a number of objects during a session.

To the right, you have the graph of Altitude vs Time, which you have seen before. This graph will change based on the object you select in the Wish List.

Next, I'll walk you through using the Observation Planner Wizard.

Using the KStars What's Up Tonight Tool

The Observation Planner includes a tool called the "What's Up Tonight Tool". This tool's functionality is identical to that of the Wizard, except that all of the selection criteria are all on one screen:



I won't walk you through the options since you have already seen them in the Wizard - experiment a little and you'll find that this screen is very easy to use. Always make sure though that you set the date and time correctly and verify that your location is accurate too.

Next Steps

Now that you understand how to us KStars, it's time to look at another planning option called Telescopius.

Mission Planning using Telescopius

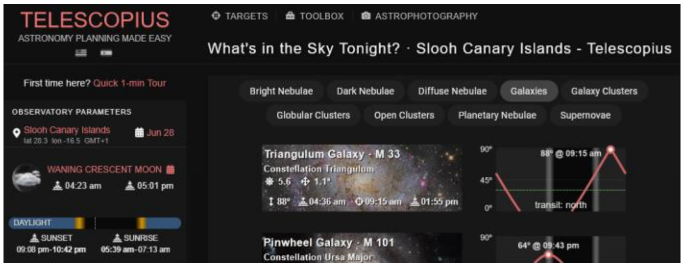
Telescopius is a very useful online planning tool. There are a lot of features and its capabilities have been improving during the years that I have been using it. Its primary functionality is similar to that of the KStars Observation Planner Wizard, except that it makes a number of selections for you, making the process even easier. Think of it as a search engine for things in the night sky.

There are two main advantages to using Telescopius

- You don't have to install anything - you just use your browser. I often find myself using it while I'm someplace where I can't install anything on the computer I'm using and want to research things to view using Slooh.

- You can list targets based on proximity to the moon. This is a fantastic feature that KStars doesn't have and is useful when the moon is full, or nearly full. You can check for targets that are far away enough from the moon to still be able to get a great image.

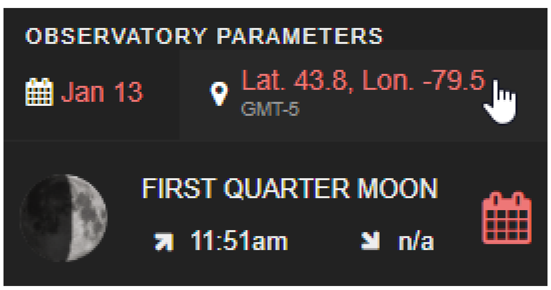
The main screen of Telescopius, at https://telescopius.com/, is shown below:



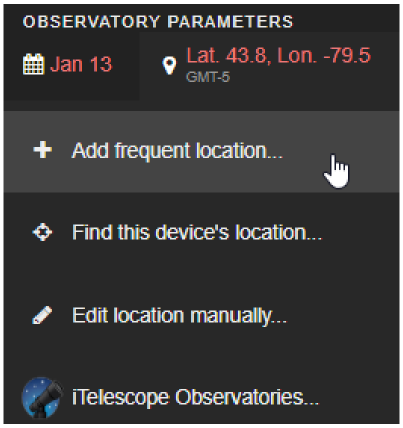
The screen is full of useful information:

- The date and location
- Details about the moon including rise and set times
- Weather and seeing conditions
- A listing of objects available for you to view

The first thing you'll have to do is set your location. Click the "Location" area as shown:



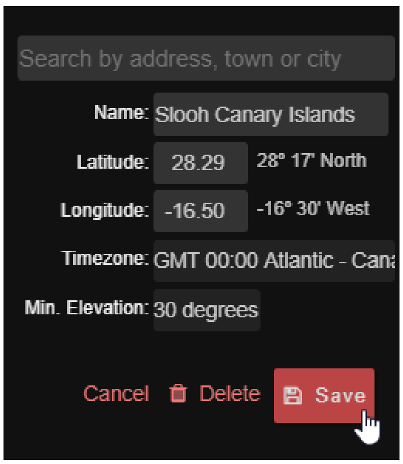
This brings up a menu - select “Add frequent location…” as shown:



Now go ahead and create an account. The process is simple, so I won’t walk you through it. Your account holds your location information so it’s easier for you to use Telescopius the next time you visit.

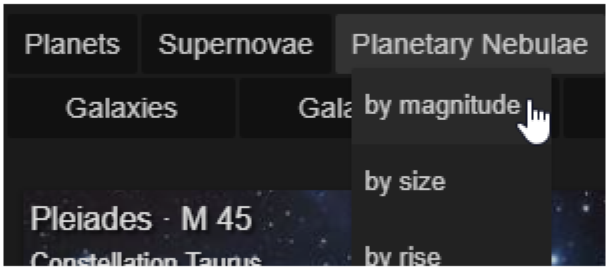
Another great feature of having an account with Telescopius is that it emails you a customized observing list before the new moon each month. I find this feature is handy because it picks the best targets for moonless observing nights each month.

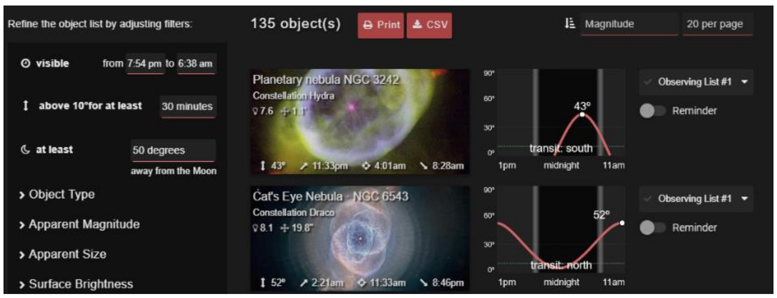
Picking up from where we left off, enter the location details as shown:



Note that the longitude is negative, the timezone offset is zero, and the “Minimum Elevation” is 30 degrees to match the pointing limits of the Slooh telescopes.

Once you have set the location, let's see what's up with Planetary Nebulae. Select Planetary Nebulae - by magnitude, as shown:

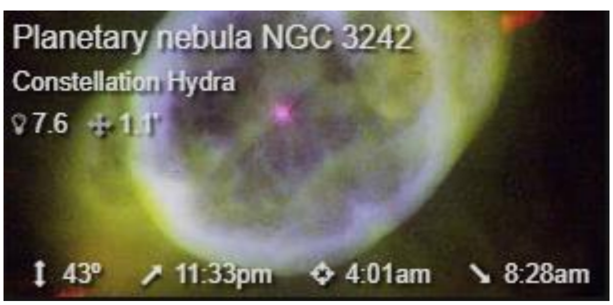




Again, the screen is full of useful information:

- The observation time window
- The angular distance of the Moon
- A listing of objects of interest
- The Altitude vs Time graph to the right of each object

Each row in the results also provides a lot of information:



- A picture of the object
- Object name and designation
- Constellation
- Magnitude
- Angular size
- Maximum elevation
- Rise time
- Transit time

- Set time

Armed with this information, you can quickly go back to Slooh and book a catalog mission really easily.

An important parameter to set on this screen is the Moon angle - it's the third option down on the left side of the screen.

This option sets the distance an object must be away from the Moon to be on your observing list. This option is important whenever the moon is up since moonlight affects the results of your observations - you usually want a nice, dark sky as a background. If the moon is close by, it can add a gradient to your images causing them to be washed out.

On full moon nights, I set this parameter to 100 degrees to ensure I get the darkest part of the sky.

Experiment with the options on the screen. The default sort order is by magnitude, so the brighter objects appear in the listing first but there are several other options to choose from.

Click the "Object Type" option on the left and choose a different type of object to filter on - there are many options.

Telescopius is a powerful search engine and I often use it even when I'm casually planning observations. Perhaps I see a free time slot on Canary One one evening, I just use Telescopius to see what's up and quickly schedule a mission.

Next Steps

Now that you know how to plan a mission, I'll show you how you can download your images.

Part III: Viewing and Downloading Images

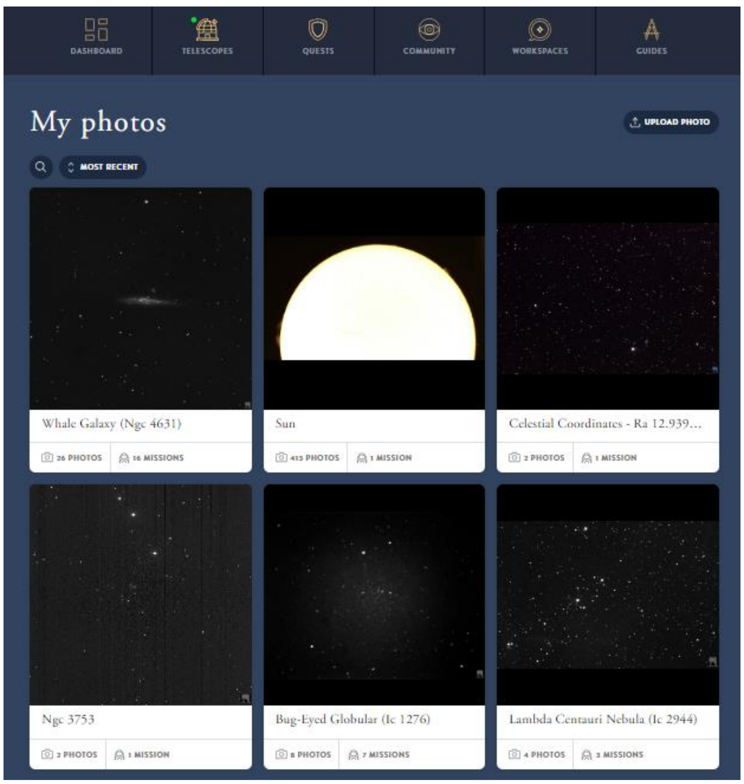
Viewing, Uploading and Downloading Images

Slooh generates a number of files and saves them in the Dashboard's My Photos section. This section goes into detail about how to view, share, and download your images. If you're an individual Apprentice or Astronomer member or the main Family account, this section explains how you can access your FITS files.

When you schedule a mission at Slooh, the next day you get an email listing the status of your missions. If you're lucky, the telescope was open and your missions completed.

You can view your images in My Photos area of the Dashboard - just select the *Dashboard* icon at the top of your screen, and scroll to the Photos section.

When you click the *View All My Photos* button, you see a list of the things you have imaged in the past, as shown:

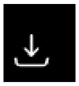
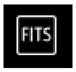


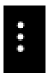
Exploring the Photo Roll

The Photo Roll is the default view when you enter the Photos section. Note that Photos are organized by object, not Mission. This means that you cannot browse through your most recent missions, but you can browse through your most recent objects.

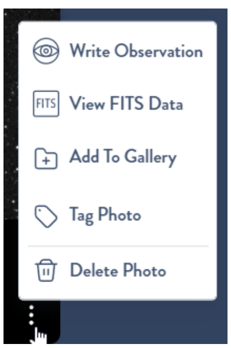
Click an object to open its page. The page shows you all of the images you have taken of the current object, regardless of what telescope it was captured on. Note that the listing starts by categorizing objects by telescope; however, as you add more and more images, the organization starts to merge telescopes, so eventually you see all of the observations from all of the telescopes together.

Each image has three action buttons:

-  Download image
- 

Download FITS files (note that this option may not be available to you if your membership doesn't include FITS files)
-  The three-dot menu, which offers a number of options, explained below

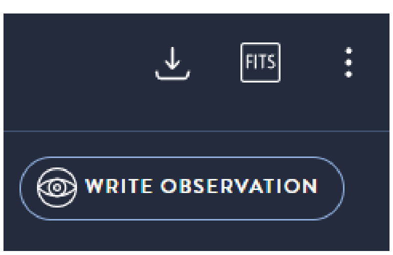
The three dot menu has several options, as shown:



We covered the first three options earlier. The Tag photo allows you to add an arbitrary tag to your photo; however, you cannot search by tag, nor do anything else with tags so this feature is not usable (photos used to be searchable by tag, but this is no longer the case).

The Delete Photo option deletes the image immediately and there's no way to undo this, so be sure you want to delete the image before you select this option.

If you click an image in the listing, you're presented with a larger version of the image along with some action buttons across the top:



- The Download button downloads a full-resolution copy of the selected image

- The FITS icon allows you to download the FITS files for the observation (this may not be available to your membership level)
- The three-dot menu contains options which we discussed previously (Write Observation, View FITS data , Add to Gallery, Tag Photo, and Delete Photo)

In addition to the image itself, the page includes information about the originating mission, discussed next.

Exploring Observation Details

The “Observer” shows you details about who took the image. In the case of a mission you Joined, your name will appear here. Your name will also appear here if you uploaded the image.

You can capture others images into your photo roll using the Join feature (refer to the section called Understanding Joining Missions), so the “Mission Scheduled By” area helps you give credit to the person who actually scheduled and took the image.

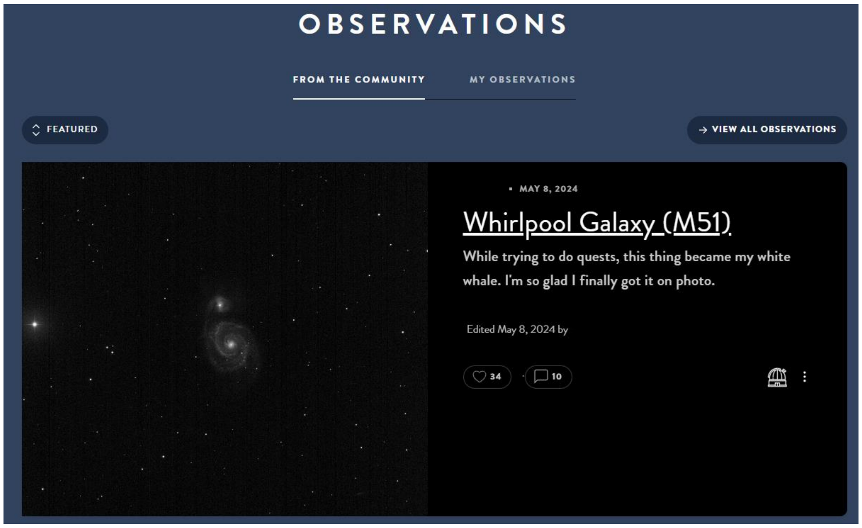
The Observatory section lists the telescope that the image was acquired with and the Mission Date shows the date of the original mission.

Sharing Your Images With The Community

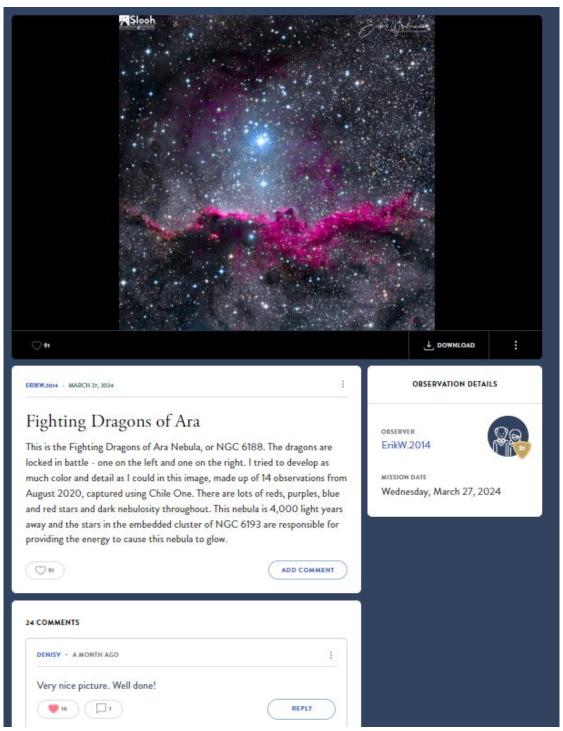
The “Write Observation” button is a way to share your image with the community, as shown:

You can enter something that’s interesting about the image and when you submit it, your image will be visible to the Slooh community.

You can see these shared images on the Slooh dashboard. The following is how Observations look on the Slooh dashboard:

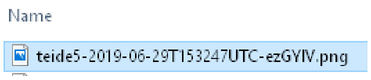


This is what an object's Observation page looks like:



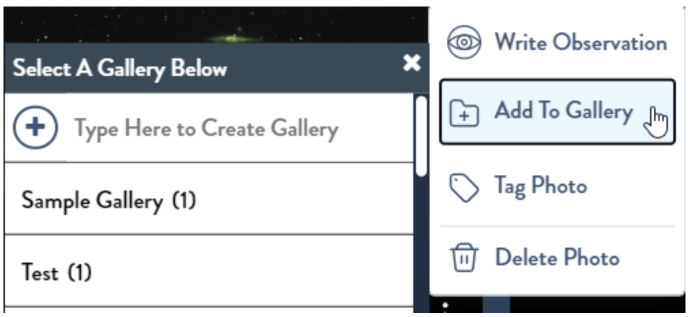
Downloading Your Images

The first icon is the Download icon. Use this to download a full resolution version of your image. Click the button and the image is downloaded to your Downloads folder on your computer (however you have configured that folder on your system). This is the file that was downloaded, as shown in Windows Explorer:



Creating and Adding To A Gallery

The fourth option is the “Add Image To Gallery” button. A Gallery is like a custom album. You can create as many galleries as you like and can arrange your images however you like. In the future, you’ll be able to share galleries. When you click the option, the following menu shows up:



Here you can add your image to an existing gallery or create one right away. The gallery is available under the Galleries tab which I explain later.

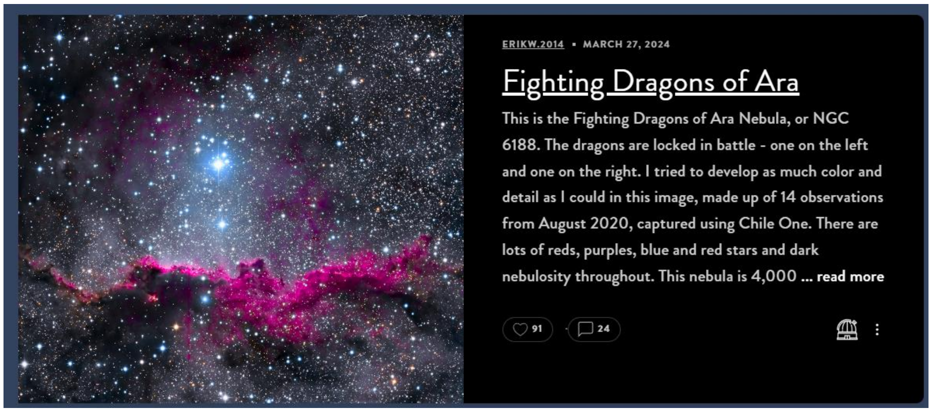
Deleting Your Images

The last icon is the Delete action. Use this carefully because there’s no way to recover your image once you delete it.

Exploring the My Observations Tab

The “Observations” tab contains images you’ve previously shared with the community. You get images into this tab by using the “Write Observation” action on your image – refer to the subheading <u>Sharing Your Images With The Community</u> in the preceding section for details.

Under the image is some information and an action button:

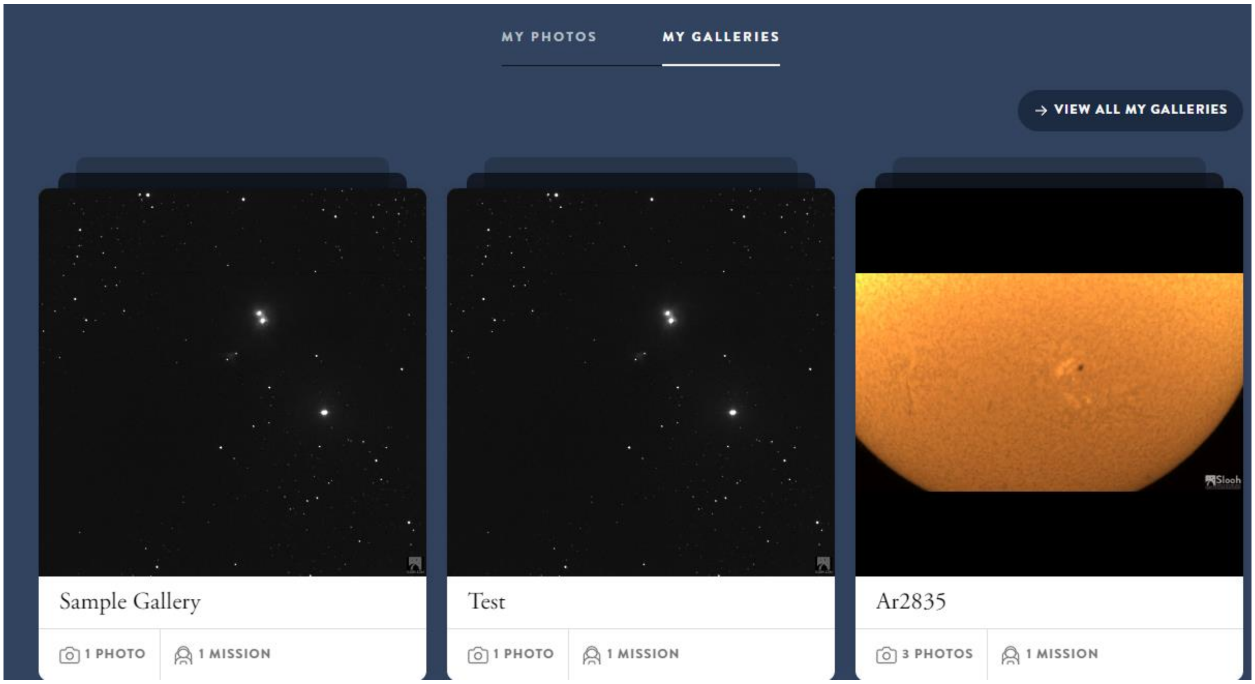


The heart icon shows the number of Likes your image received and the icon next to it shows the comments your image received.

I describe the Galleries tab next.

Exploring the My Galleries Tab

When you create a Gallery, it ends up on this tab as shown:



Here I have created a Gallery and you can see its details about when it was created. Click the image to view the contents of the Gallery.

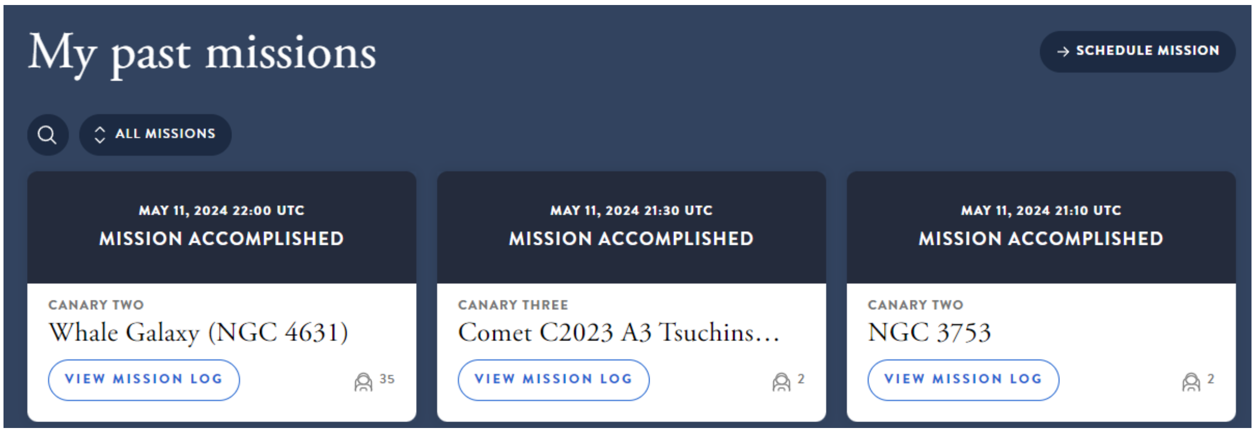
The images in the Gallery are displayed when you click “View Details” and the functionality of the images in this tab is identical to what you saw in the “Exploring the Photo Roll” section.

Exploring the My Past Missions Section

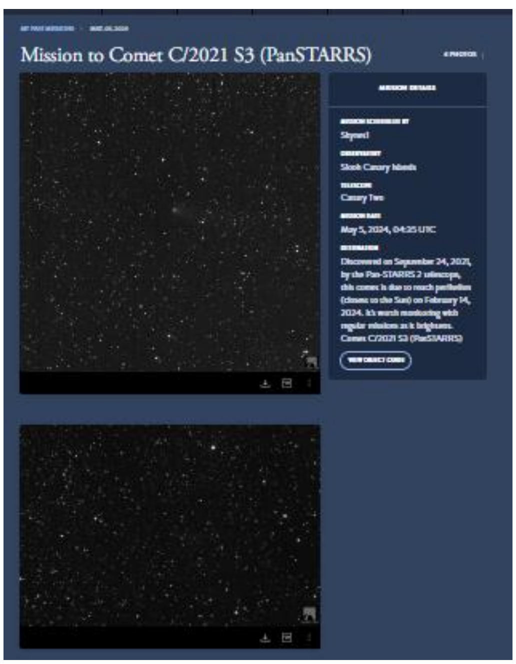
The “My Past Missions” Section contains the images you captured using any of the types of missions (Slooh 1000 List, By Catalog, By Constellation, or By Telescope).

The functionality of this screen is a little different from the previous sections.

You’ll notice immediately that the listing of images has changed. Now, the mission details are shown along with a View Mission Log button.



Clicking the View Mission Log button takes you into the mission’s details:

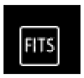


The screen shows you the images that were either captured or processed during this mission. In my case there are four images – you could have as few as one image for the Canary Three telescope.

The functionality of the images on this screen is identical to that which you saw in the “Exploring the Photo Roll” section – you can download an image, write an observation, tag the image, add to a gallery, or delete or share the image.

There are four images because the telescope gathers images using various filters. I explain these filters later (refer to Understanding FITS Files) however, the images here represent the images taken using the Luminance filter and the combined LRGB images.

All of the images have been processed using the “Processing Option” that you either selected or was selected for you when you booked your mission. For example, if you book a Slooh 1000 List mission, the Processing Option is chosen for you; however, you can choose your own Processing Option using the other reservation methods (refer to Understanding Processing Options). For now, you can use the color images for your final image and to use to enhance your image to share with others if you like.

Click the 

button to reveal a larger screen that lists the FITS files available for this mission. FITS files contain the data the telescope actually captured during the mission. FITS files are not images – they are large text files that require special software. One specialized software is called JS9 and it is integrated right into Slooh – you don’t have to install anything to use it and I demonstrate its usage in the next section, “Using JS9 - Slooh’s Integrated FITS Viewer”.

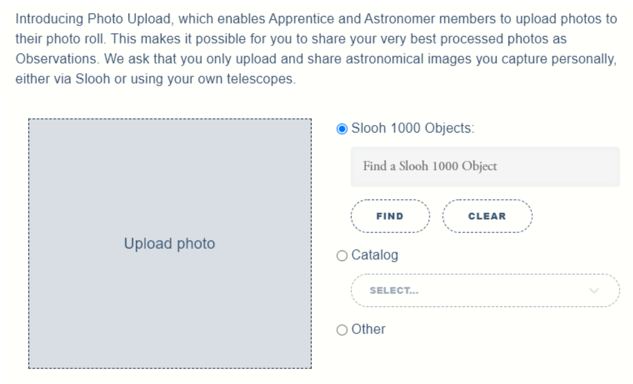
I also explain what FITS files are and how to use them in the second half of this book (refer to Understanding FITS Files) since they are an advanced and powerful option for processing your images.

You can download a FITS file just by clicking the Download button  next to where it says View FITS. The name of the FITS file indicates what filter was used to capture the image. An image ending in “_l_cal.fit” represents the luminance filter, “_r_cal.fit” represents the red filter, “_g_cal.fit” represents the green filter, and “_b_cal.fit” represents the blue filter. If the telescope has two telescopes you’ll find the files for the other telescope as well.

Refer to Understanding FITS Files for a more detailed discussion about FITS files and what you can do with them.

Uploading a Photo

You can upload photos to share them with the community or just store them in your photo roll. Click the ‘Upload Photo’ button to start the upload process:



Click the ‘Upload photo’ label in the box to select a photo to upload. Once uploaded, you can identify the object as a Slooh 1000 object, a Catalog object, or some other object.
For Slooh 1000 objects, enter the common name in the Find box, click ‘Find’, and select the correct object.

For Catalog objects, click Catalog, select the correct catalog and enter the designation in the box provided.

If the object cannot be classified as a Slooh 1000 or Catalog object, select Other.
You can optionally give your object a title and provide a description.

Click ‘Upload Selected Photo’ to upload it to your photo roll.

If you want to share your uploaded photo, click the View Details option, and then select ‘Share Photo’ at the top of the screen, then select a club where you wish to share your photo. Once your photo receives at least 10 Likes, you’ll see it on the dashboard in the Community section.

The next section demonstrates how to use Slooh’s integrated FITS viewer.

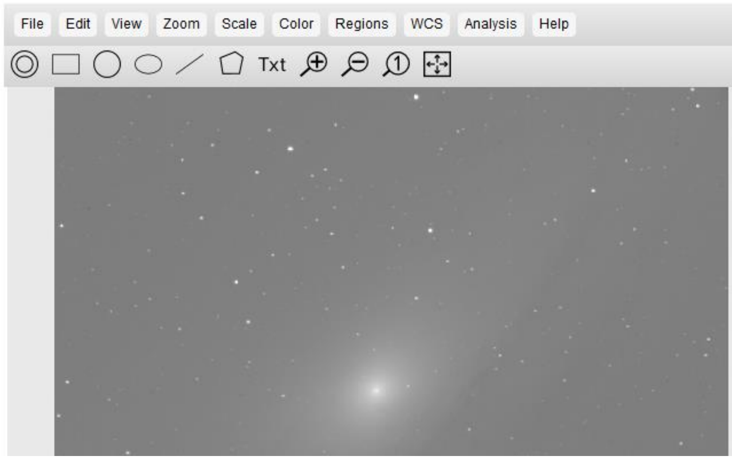
Using JS9 - Slooh’s Integrated FITS Viewer

Slooh’s integrated FITS viewer is one way to see what your FITS files contain. This section introduces you to the viewer and its basic functionality. For more details and to learn how to produce full color images, refer to the section <u>Producing A Full Color Image Using JS9</u>.

You access the FITS viewer, called JS9, by clicking the “View FITS” button next to a FITS file from a Mission. Here are the step-by-step directions for viewing a FITS file using JS9:

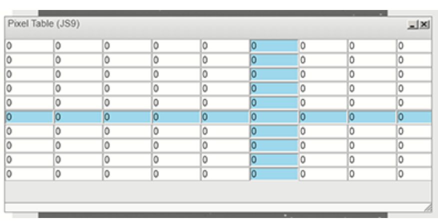
1. In your Photos area, choose an image and click it
2. Click the button next to the Download button labeled *View FITS*

When the viewer comes up, it can take a moment for your image to appear while it downloads, so be patient. Here’s a partial screenshot of what the viewer looks like when an image is loaded:



Your image might be washed out and look grey, so a small adjustment is necessary. We need to adjust the black point of your image to make the background darker and make the details more visible.

From the View menu, select Pixel Table. This brings up a new window as shown:



You can move this window out of the way of your image by clicking and dragging the title bar of the Pixel Table.

Move your mouse around the image and the Pixel Table will update the numbers in it with the values of the pixels in the image. The point at where the table intersects is the value of the pixel right under your pointer. Move your mouse around the image's darker areas – places where there aren't any stars or nebulosity. You're looking for the lowest pixel value you can find in your image. In my image the lowest value I found was 175. You don't have to be precise here – we just want a low pixel value from your image.

Once you have found a low pixel value, select Scale and enter the value you found in the 'low' box and press Enter on your keyboard. JS9 adjusts the image when you press Enter and you can click anywhere on the image to dismiss the menu' also close the Pixel Table since we don't need it anymore.

You are now looking at an image captured directly from the telescope without any additional processing done on it (except calibration, which I explain in Understanding FITS Files). You can download the image by selecting File – Save, and select JPEG or PNG. Your browser will download the file to the same location where you save all of your downloaded files.

You can do quite a bit with JS9, including producing full color images. I show you how to do that in the section Producing A Full Color Image Using JS9.

Next Steps

Now that you understand the images Slooh produces for you and have seen what else is possible, it's time to explore the other files Slooh produces for you: FITS files. FITS files contain a great deal of information and are very useful not only for producing better images, they're also useful for doing things like scientific measurements and reporting observations to governing bodies like the MPC. But first, you'll gain an understanding of color and filters.

Part IV: Image Processing

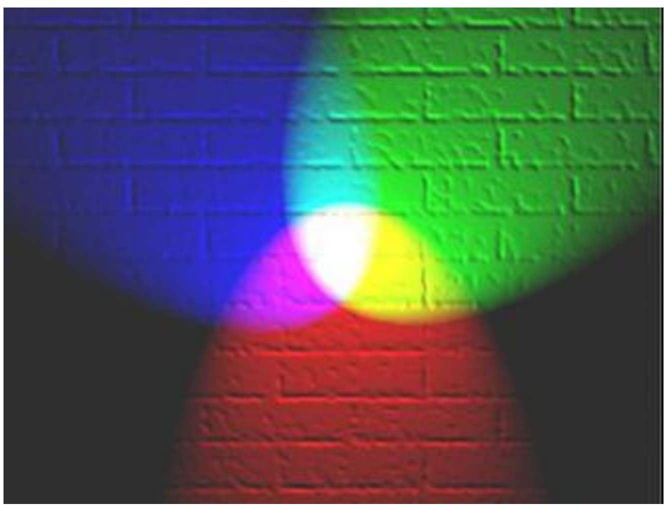
Understanding Color And Filters

Before we can get into image processing, you'll need to understand a little about color, the filters the Slooh telescopes use, and how the chips that collect the images from the telescope work. This background information will help you understand what you're looking at and understand any limitations you might encounter.

Understanding Color

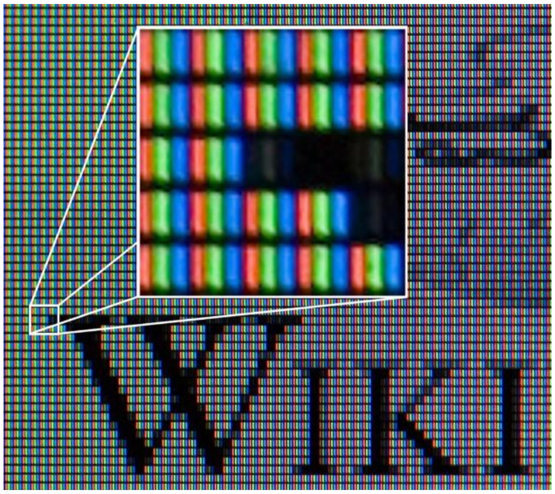
For computers, all color is represented using three fundamental colors: red, blue, and green. There's a long history to this and I invite you to read the Wikipedia articles about this for all the background information - I list the links in the Online Resources section.

Here's an image from Wikipedia that does a great job of demonstrating how red, blue, and green combine to produce different colors:



From the image, you can see in the center that a combination of all three colors produces white, whereas combinations of only two of the colors - for example red and blue - produce a secondary color - in this example, red and blue produce purple.

Your screen displays its image to you using millions of pixels - individual dots that together make a whole image. Here’s a closeup of an LCD screen along with an inset that’s been magnified a great deal:



(image credit: Ravedave on Wikimedia.org)

From the image, you can see the white areas and darker areas where there’s the lettering. The inset shows the white area with a part of the W. The inset shows that the pixels of the white area are showing R, G, and B to make white and are showing all of the pixels showing a zero value (essentially off) to show black.

An image file you get from a camera works the same way. The file contains information about all of the pixels that make up the image encoded with RGB information.

The values for red, blue, and green are individually adjustable and are represented using a number between zero and 255. If I wanted to, for example, encode a red pixel, I would do it like this: rgb(255, 0, 0). What this means is that the red component of the pixel is completely on at its maximum value, whereas the blue and green components are completely off.

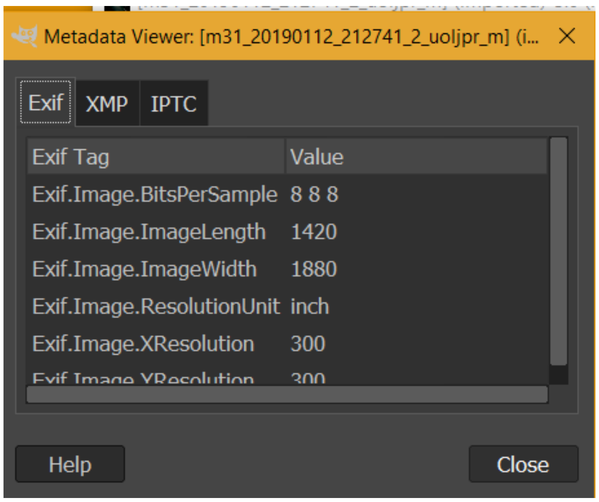
If I wanted to encode the color purple, I would do it like this: rgb(128,0,128). This means the red component is at 50% intensity (128 is about half of 255), the green component is at zero, or off, and the blue component is also at about 50%. Refer to the earlier image of the combination of colors to see how purple was created by combining red and blue.

The RGB information in an image has fidelity, which represents the available range of colors it can represent. When you encode RGB information using numbers between 0 and 255, the fidelity is limited to 16,777,216 total colors that can be represented. While that’s certainly a lot of color, we often need better fidelity for astronomical images.

We need more fidelity because the colors in astronomical images are pretty limited. When you have seen a number of astronomical images, you’ll start to notice that colors like, black, red, blue and sometimes green are very prevenient. You won’t come across brown, yellow, orange, or a broad range of other colors. Note that there is an exception to this - narrow-band and false color images- both are specialized types of images and you’ll often come across these when viewing Hubble images and some amateur astronomers’ images. Here, I’m discussing images you get directly from Slooh.

As far as computers go, the fidelity I described earlier where RGB is encoded with values between 0 and 255 is said to be “8 bits”. The details are rather technical and I won’t go into them here; however, I do include some links in the Online Resources section for further reading about bit depths. Images can be encoded to include greater fidelity, or bit depths, like 16 bits, 24 bits, and 32 bits.

The PNG files you get from Slooh are encoded using 8-bits as shown in the following screenshot from GIMP:



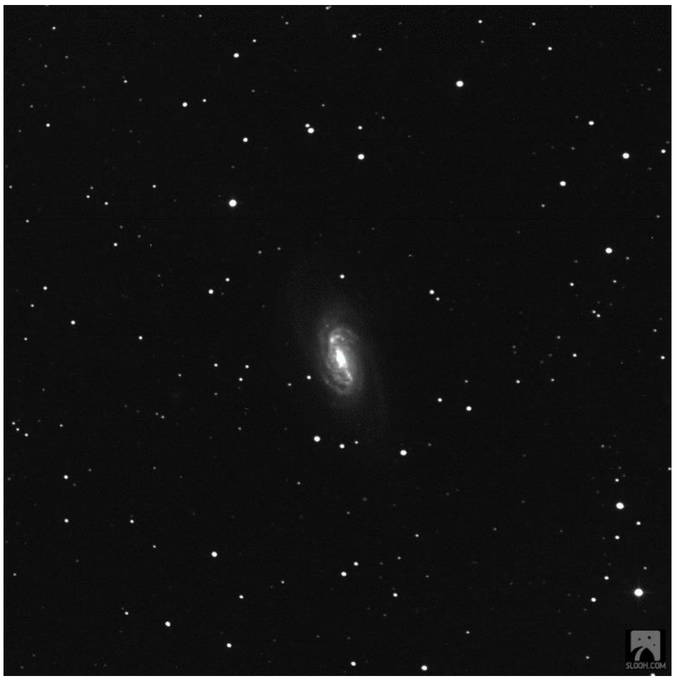
The first line, Exif.Image.BitsPerSample indicates that the RGB values are stored using 8 bits.

The FITS files you get from Slooh include much more fidelity and are encoded using 32 bits.

Understanding The Filters Slooh Uses

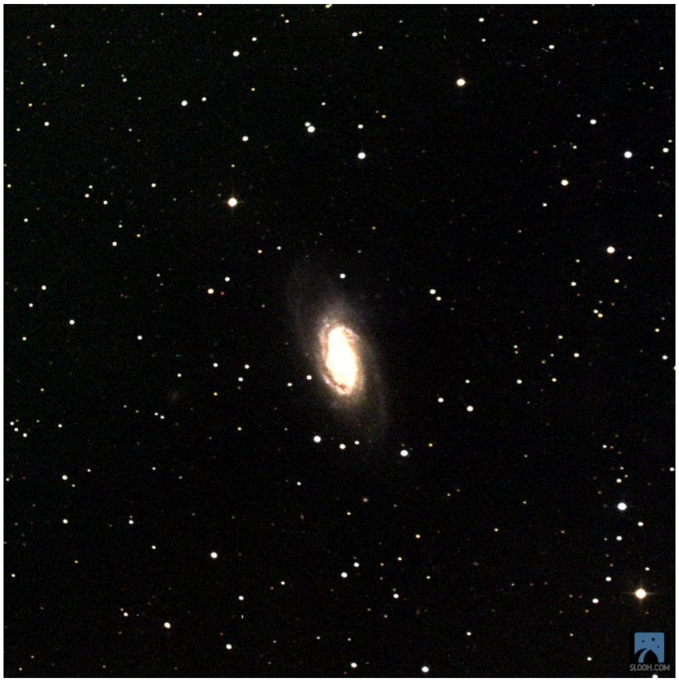
The telescopes at Slooh only “understand” pixel intensity values. This means the camera that collects the information that ends up in your image only records how much light a particular pixel collected while the exposure was being taken, so you can say the image is effectively a black and white, or monochrome image.

This is an image from Slooh which represents only the amount of light that was collected:



The image does not have any color information - it represents only the amount of light that the telescope collected during the exposure.

Here's the same image, except this time there's color information included:



You can clearly see the galaxy, the S Galaxy (or NGC 2903), has a yellow cast to it while the stars vary between yellow and white.

So how do you get a color image from a monochrome image? This is where filters come into play.

Before we go on, this discussion includes all of the telescopes at Slooh, except for Canary Three. Canary Three does not use filters. Instead, Canary Three uses a color camera to capture photos in one shot.

The way the Slooh telescopes work, is they take the same image several times, each time using a different filter. A filter ensures only a specific color of light passes through it so that the light reaching the camera is only of a particular color. Slooh uses four filters:

- Luminance - this is a 'clear' filter which lets through all light - this filter is usually shortened to just L
- Red - this filter allows only red light through - the name of this filter is usually shortened to just R
- Blue - this filter lets only blue light pass through to the camera - the name of this filter is usually shortened to just B
- Green - this filter passes green light - the name of this filter is usually shortened to just G

Although the details vary between telescopes and settings used when booking a mission, the process of taking a picture usually runs like this:

1. Take a luminance image
2. Take a blue image
3. Take a green image
4. Take a red image

The problem is that the underlying camera can only ‘see’ black and white, regardless of what filter we use.

This is where software comes into play. What happens at the end of a mission is the software that handles images combines them into what’s called an LRGB image. The software ‘knows’, for example, which image was taken using the red filter and so it casts the image using red. It does the same for each color and uses some math to combine all of the images into a single color image (or LRGB image). In fact, if you look at the file name of the color image you download from Slooh, you’ll see that it ends in “lrgb”, indicating it is a combined image.

By creating color-combined PNG images for members to use, Slooh also saves us a lot of time by stacking and processing the images for us. However, Slooh tries to reach a good compromise between image quality and processing speed and so does not produce the best possible image for us. This is where processing, and as a result, stacking comes into play.

Next Steps

The next section discusses FITS files in detail.

Understanding FITS Files

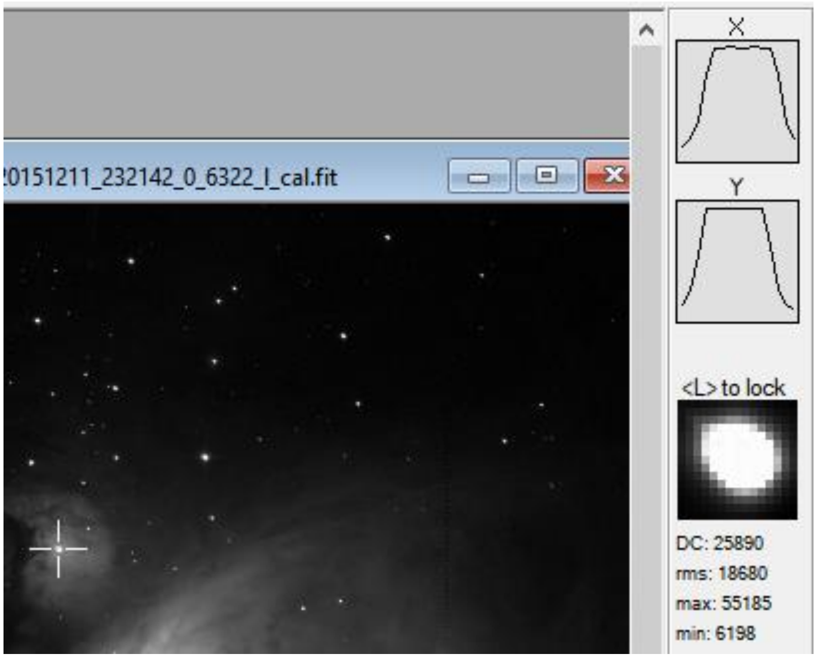
FITS is short for Flexible Image Transport System - it’s a standard that was developed during the 1980s which defines a digital format for the storage and transmission of image data.

When you look at a JPG, PNG, or TIFF image, you’re looking at the values of pixels encoded with color information. Each pixel on the image has color information associated with it and the colors are represented using a combination of red, blue, and green values.

The problem with this format is that you don’t have intensity information. All you have is color. You can represent dimmer pixels using another color, like gray for example, yet you fundamentally don’t have any information about how much light a pixel on the image represents. This is where FITS comes in.

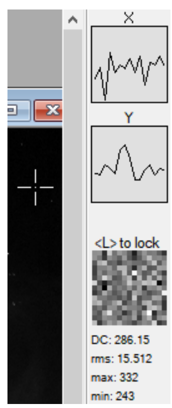
When an image is read off the CCD camera in the telescope, it records the pixel values coming off the CCD. The CCD records the intensity of light that it captured while it was exposed to the target you’re looking at. FITS files contain details about this intensity information. When we display a FITS image in black and white, we use different shades of gray to represent different intensities; however, the intensity values are still available to us.

For example, I have opened an image of M 42 in software called Fitswork as shown:



I have the crosshair on the star shown to the right side of the screen. You can see the pixel values beside "max" and "min" below the star on the right side of the screen. The graphs also indicate that the pixel values get clipped at their maximum value.

Even dark areas have pixel values that are non-zero, as shown here:



From the graphs, you can see the pixel values fluctuate quite a bit between a minimum of 243 and a maximum of 332. When converted to a color image, chances are that this pixel intensity information gets lost and gets replaced with different hues of grey (although it would be very dark gray in this case).

Moreover, the FITS file contains some other information about the observation too, as shown:

Fits Header

```
DATE-OBS= '2015-12-11T23:20:39' /YYYY-MM-DDThh:mm:ss observation start, UT
EXPTIME =   50.000000000000000 /Exposure time in seconds
EXPOSURE=   50.000000000000000 /Exposure time in seconds
SET-TEMP=  -35.000000000000000 /CCD temperature setpoint in C
CCD-TEMP=  -35.000000000000000 /CCD temperature at start of exposure in C
XPIXSZ  =   18.000000000000000 /Pixel Width in microns (after binning)
YPIXSZ  =   18.000000000000000 /Pixel Height in microns (after binning)
XBINNING=                    2 /Binning factor in width
YBINNING=                    2 /Binning factor in height
XORGSUBF=                    0 /Subframe X position in binned pixels
YORGSUBF=                    0 /Subframe Y position in binned pixels
FILTER  = 'Luminance' /          Filter used when taking image
IMAGETYP= 'Light Frame' /        Type of image
SITELAT = '28 17 59' /           Latitude of the imaging location
SITELONG= '-16 30 30' /          Longitude of the imaging location
FOCALLEN=   2939.0000000000000 /Focal length of telescope in mm
APTDIA  =   432.00000000000000 /Aperture diameter of telescope in mm
APTAREA =   138341.22691133319 /Aperture area of telescope in mm^2
SWCREATE= 'MaxIm DL Version 5.06' /Name of software that created the image
SBSTDVER= 'SBFITSEXT Version 1.0' /Version of SBFITSEXT standard in effect
FLIPSTAT= 'Flip/Mirror'
CSTRETCH= 'Medium  ' /           Initial display stretch mode
CBLACK  =                  881 /Initial display black level in ADUs
CWHITE  =                 8827 /Initial display white level in ADUs
```

In pretty much any FITS-capable spftware you can open any FITS file and view the FITS information.

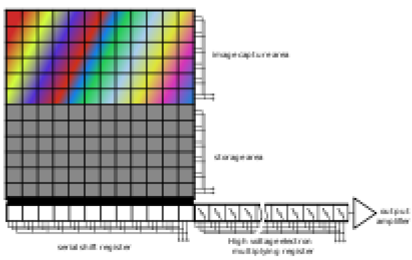
Upon closer inspection, you'll find information about the telescope, exposure time, camera temperature, filter used, what was done to the data before you got it (like dark subtraction), and even the name of the software that produced the file. This information is relevant when you want to know more about the image and its characteristics.

Before going into using a FITS file, you need to understand what happens to the FITS data before you get it from Slooh, since Slooh does something important that saves a great deal of time and effort on our part.

Understanding Calibration

A digital camera uses something called a CCD instead of film to capture images. The term CCD expands to Charge Coupled Device and the name is derived from how the CCD works to acquire an image.

A CCD is made up of an array of light-sensitive sensors arranged in a flat square. The following image provides a conceptual view:



(image credit: https://en.wikipedia.org/wiki/Charge-coupled_device)

The sensors collect data about the amount of light that they capture and then that data needs to be read off the CCD chip. The process of reading data off the chip involves shifting the data around the sensor array and off the bottom to a converter that transforms the raw data into something we can use (this is shown at the bottom of the preceding image).

CCDs are electronic devices and all electronic devices have intrinsic noise within them due to the electricity flowing through them and as a result of the nature of the how the sensors work. This noise translates into various artifacts that you can see on your final images.

Examples of noise introduced by a CCD include:

- Hot and dead pixels – a hot pixel always registers some reading of light even when there’s no light falling on it. Conversely a dead pixel never registers a reading of light.
- Noise from the temperature of the CCD – CCDs are cooled to around -30C to try to reduce noise from temperature but the effects still remain
- Non-zero pixel values (bias) – even when there’s no light at all, pixels will still report a reading. It will be a very small reading but it can be enough to affect your final images.
- Noise from ‘dark current’ – This causes pixel values to be higher than they actually were when they were collecting light
- Light leakage – this can happen due to some manufacturing defect or some misalignment between the camera and telescope

The common thing to all of these factors is that they’re always present in that they don’t vary much between imaging sessions.

Calibration attempts to reduce these effects by using images captured from the telescope when it isn’t collecting any light. Someone that’s operating a telescope and CCD takes pictures called ‘darks’, ‘flats’, and ‘bias frames’ by following a procedure to collect these images. These images are then stored in a library and used to remove the artifacts I mentioned previously. This library needs to be updated whenever there’s a change to the telescope or CCD. For example, if the

CCD is cooled to -30C during one session and cooled to -35C in another session, a new calibration library is needed as a result of the change.

Once you take your images, the images in the calibration library are used to remove the noise from them. This process is done by your imaging tool – AstroImageJ has the functionality built right into it to be able to process your images in bulk.

Fortunately for members of Slooh, this calibration process is done for us. Slooh maintains its own calibration library and updates it whenever they do maintenance on the telescopes. When you get either a PNG or FITS image from Slooh, it has already gone through the calibration process. You can confirm this by viewing the FITS header of your image (don't worry if you don't understand what a FITS header is for now):

```
HISTORY Bias Subtraction (Bias 2, 2048 x 2048, Bin2 x 2, Temp -35C,
HISTORY Exp Time 0ms)
CALSTAT = 'BDF     '
HISTORY Dark Subtraction (Dark 13, 2048 x 2048, Bin2 x 2, Temp -35C,
HISTORY Exp Time 50s)
HISTORY Flat Field (Flat Luminance 1, Luminance, 2048 x 2048, Bin2 x 2,
HISTORY Temp -35C, Exp Time 9s)
HISTORY Filter Kernel
HISTORY Process Remove Bad Pixels
```

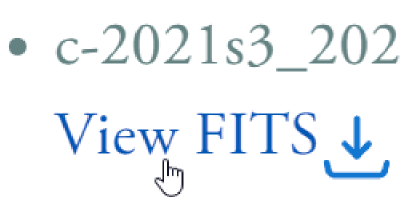
The header information indicates that the 'bias', 'dark' and 'flat field' frames have been removed from the resulting image.

The fact that Slooh does this for you saves you a lot of time when processing your images and significantly boosts the quality of images Slooh produces for you.

Slooh produces several types of FITS files, that's the focus of the next section.

Understanding the Different FITS Files You Get From Slooh

To download the FITS files for your mission, click the FITS download button on your mission's image, as shown:



For a reminder of how to view your mission's images, refer to Exploring the My Past Missions .

Slooh produces several different types of FITS files, each containing unique information. Here's a screenshot of the FITS files available for you to download from a reservation on the Canary One telescope:

Canary Two
MISSION DATE
May 5, 2024, 04:35 UTC

- c-2021s3_20240505_043505_0_lihbad_l_cal.fit
  View FITS
- c-2021s3_20240505_043553_0_bn3imu_r_cal.fit
  View FITS
- c-2021s3_20240505_043629_0_r8dlba_g_cal.fit
  View FITS
- c-2021s3_20240505_043705_0_4hrd3a_b_cal.fit
  View FITS

- c-2021s3_20240505_043513_0_ae1lmd_l_cal.fit
  View FITS
- c-2021s3_20240505_043559_0_duegmt_r_cal.fit
  View FITS
- c-2021s3_20240505_043640_0_gz2bid_g_cal.fit
  View FITS
- c-2021s3_20240505_043724_0_ul3hdr_b_cal.fit
  View FITS

The file names vary but the information they convey is similar. In this example, the FITS file are for a mission C 2021 S3 as indicated by the beginning of the filenames. Skipping to the end of the filenames, you'll see single letters like L, R, G, and B. These letters represent the filter that was in use when the FITS data was being captured - in other words, the filter that was in place when the telescope was capturing the image.

The "cal" at the end of the filename is a reminder that the FITS data has already been calibrated, as discussed in the preceding section.

The other parts of the filename are the date and time the image was taken (2024-05-05 at 04:37:24 in this example). The characters that follow are randomized characters to make the filename unique.

Depending on the mission you booked and the telescope, the file names will change but the information it conveys is the same. Let's look at a coordinate mission on Canary One again:

Canary Half Meter
103843p484918_20190110_033528_1_wpr3nf_l_cal.fit
103843p484918_20190110_033648_2_phitan_l_cal.fit
103843p484918_20190110_033808_3_otkecm_l_cal.fit
103843p484918_20190110_033952_4_amj4jn_r_cal.fit
103843p484918_20190110_034117_4_cwba9q_g_cal.fit
103843p484918_20190110_034245_4_qgrv5h_b_cal.fit

In this case, the target name has been replaced by the Right Ascension and Declination of the object I imaged (in this case it's RA 10:38:43 and Dec +48:49:18). The rest of the filename is the same as you saw earlier: the date and time, followed by some random characters, the filter used, and "cal" for calibrated.

Here's an example of the FITS files from Canary Two:

FITS DATA

Comet C/2021 S3 (PanSTARRS)

Scheduled by

TELESCOPE

Canary Two

MISSION DATE

May 3, 2024, 04:50 UTC

- c-2021s3_20240503_045059_0_peyxyc_l_cal.fit
  View FITS
- c-2021s3_20240503_045147_0_eygzmt_r_cal.fit
  View FITS
- c-2021s3_20240503_045223_0_kalt6l_g_cal.fit
  View FITS
- c-2021s3_20240503_045258_0_tdabzb_b_cal.fit
  View FITS

- c-2021s3_20240503_045105_0_8zcksh_l_cal.fit
  View FITS
- c-2021s3_20240503_045151_0_94zzqc_r_cal.fit
  View FITS
- c-2021s3_20240503_045231_0_u8vkqc_g_cal.fit
  View FITS
- c-2021s3_20240503_045315_0_ehedjj_b_cal.fit
  View FITS

Canary Two has two telescopes - the wide field and ultra-wide field, therefore you get two sets of FITS files. From this example, you can see that I didn't use any filters since all of the filenames end in L - for the luminance, or clear filter.

Here's an example from Canary Three:

Canary Deep Sky

m45_20190113_005507_0_yxuo0w_m_cal.fit

m45_20190113_005703_1_bqlgcz_m_cal.fit

This telescope is a little different - it produces only two files and both end in the M designation. The M means that this is a color image and all of the filters have been combined into one image (so you don't get the L, R, G, or B files).

Canary Four produces files similar to Canary One.

Here's the output from the Chile telescope:

FITS DATA

SAO 151881

Scheduled by ErikW.2014

TELESCOPE

Chile Two

MISSION DATE

Apr 4, 2024, 23:50 UTC

- sao151881_20240404_234854_0_8rabjm_r_cal.fit
  View FITS
- sao151881_20240404_234950_0_w4q3w1_g_cal.fit
  View FITS
- sao151881_20240404_235033_0_rycgnq_b_cal.fit
  View FITS
- sao151881_20240404_235141_1_fm0xmb_l_cal.fit
  View FITS

This mission is for a star called SAO15188 and this example uses all four filters (L, R, G, and B).

Producing A Full Color Image Using JS9

In an update around November 2019, Slooh added an FITS viewer that's integrated right into the website. As you learned previously, FITS files contain the raw data the telescope collected during your mission. This type of file is used to extract the most information from an astronomical image and is useful for scientific measurement. FITS files are also used by members to process and produce their own images, often resulting in images better than those the automated algorithms that Slooh.com uses to produce the PNGs in your 'My Photos'.

Because it uses a special format, viewing a FITS file requires specialized software, like FITS Liberator by ES/ESO/NASA. While FITS Liberator is free, you have to download and install it on your system, plus it requires more adjustments to get a good final image.

The content in this section demonstrates how you can use JS9 to process your FITS files to produce full-color images that are suitable for your final image or further processing using something like Photoshop, GIMP, or the online image editor Photopea

Let's start by opening JS9.

Review your missions in 'My Photos' under the Missions tab and find a suitable target. The PNGs that Slooh.com produces will give you a good idea about how bright and large your target is before you view the FITS file. Click the FITS icon

This brings up a listing of the FITS files that make up your mission:

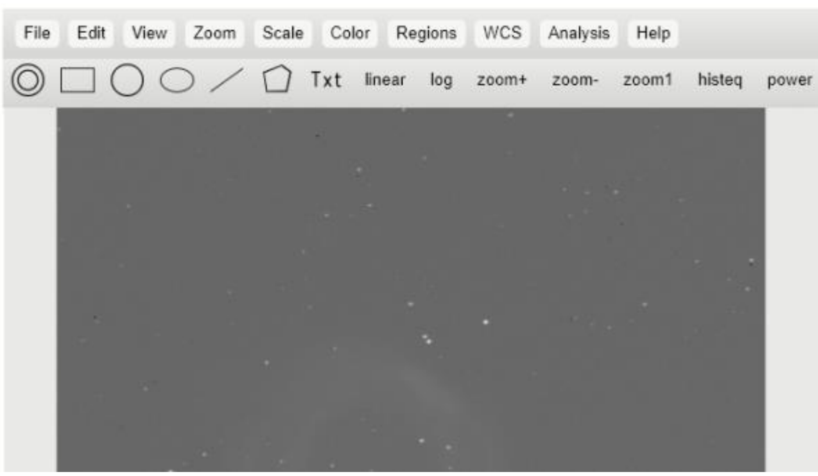
Chile Two

MISSION DATE

Apr 4, 2024, 23:50 UTC

- sao151881_20240404_234854_0_8rabjm_r_cal.fit
  View FITS
- sao151881_20240404_234950_0_w4q3w1_g_cal.fit
  View FITS
- sao151881_20240404_235033_0_rycgnq_b_cal.fit
  View FITS
- sao151881_20240404_235141_1_fm0xmb_l_cal.fit
  View FITS

Under each filename there are two action buttons: View FITS and a download button. Note the filenames and select 'View FITS' on a file that ends in 'r_cal.fit', 'g_cal.fit', or 'b_cal.fit'. This opens JS9 in a new window (note that it takes a few seconds to display your FITS file in JS9, so be patient while it loads):



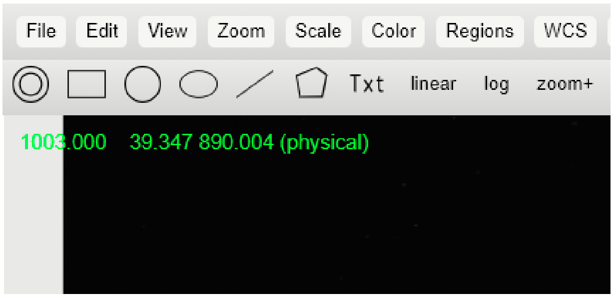
Chances are your image looks much like mine does: washed out with little detail. To fix this, we need to apply a stretch function and then adjust the black point of our image.

Selecting a Stretch Function

A stretch function distributes the pixels that make up your image in such a way that it makes it easier to view and improves contrast. There are many stretch functions, so let's explore a couple of them.

The 'Scale' menu contains stretch functions as well as other capabilities that affect your image.

From the menu, select ‘Scale’ and then select ‘linear’ – your image will darken quite a bit, similar to the following:



Try another Scale function, like ‘histeq’, or ‘asinh’ to see the effect. As you make your selections, you are only manipulating the FITS file in memory – you are not affecting the FITS file stored in your ‘My Photos’ area or on your system.

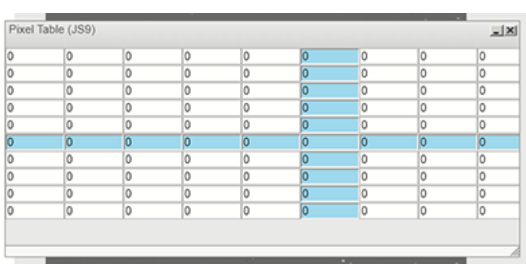
The ‘log’ scale function is the most useful for most images you open in JS9, so select it to return to where your image was when you opened it (the log function is the default for JS9).

The image is washed out because the black point is set too low at the moment. You can adjust the black point by first measuring the darkest part of your image and then making the adjustment.

Measuring the Pixel Values In Your Image

You can measure the pixels in your image in a couple of different ways, however, the easiest is to use something called a Pixel Table. A Pixel Table simply shows you the value of the pixel under your mouse pointer in a large and easy to read table format.

Open the Pixel Table by selecting ‘View’, ‘Pixel Table’ from the menu. This brings up the pixel table as shown:



You can move the pixel table out of the way of the image by clicking and dragging at the top of the table.

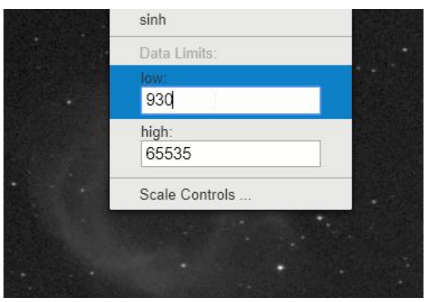
Use your mouse to hover over different parts of your image and note the value displayed at the center of your pixel table:

54	55	56
970.0	943.0	992.0
991.0	961.0	1074
995.0	940.0	1039
1056	949.0	1070
996.0	1027	975.0
973.0	984.0	933.0
977.0	995.0	1002
979.0	964.0	1018
984.0	1059	989.0

You want to find an area of your image that's dark and doesn't have any stars or nebula in it. Your goal is to find the lowest value in your image. In my image, I found that the lowest value is around 930. You don't have to be completely precise – you can always change the value later.

Setting the Black Point of Your Image

Once you find a low value, close the Pixel Table by clicking the X at the top right. Now that we have measured the black point of our image, let's set that value for our image. From the menu, select Scale, enter the value you measured into the box marked 'low', and press Enter to make the change to your image. You'll notice your image becomes darker and you can now see more detail:



Click anywhere on the image to dismiss the menu.

Opening Multiple Images

So far, we have just one image open and we need to open more images to combine them to produce a full-color image. JS9 only downloads your first image from Slooh.com directly – you'll have to download and open images from your computer to open all of the images from your mission.

Download the remaining images from your mission to your computer (you can switch back to Slooh.com in the previous tab).

You can open multiple files in JS9 – the only limitation is the amount of available memory on your system.

There are a couple of ways of opening a file in JS9: you can select 'File', 'Open' from the menu and browse to find the file you downloaded, or you can simply drag the file from Windows Explorer onto the JS9 window.

For now, open the two remaining R, G, or B files that make up your mission (you previously opened on of the R, G, or B files above so now open the remaining two).

Understanding the Active File

From the File menu, you can see which file is the one in your view because it is marked with a yellow and green dot next to the name. We'll be switching between files during this tutorial.

Let's make the Red file the active one, so select File, find the filename ending in 'r_cal.fit' and select it.

Chances are that your image is zoomed in, so from the menu select 'Zoom', 'zoom to fit'.
Adjusting the Black Point of Your Other Images

If your image is washed out, you need to measure and adjust the black point of your image, so go ahead and do that for each image, following the directions above to measure and adjust the black point.

Assigning Color To Your Images

Now it's time to assign color and combine the image into a full-color image.

You'll have to know which image you're working with to create a color image. You can tell which image you're working with based on the filename, but there is a more reliable way: view the FITS header. The FITS header has a field called 'Filter' which tells you which filter was in use to capture the image. Select 'File', 'display', 'FITS header' to view the header and look for the field 'FILTER'.

Go back to the Red file, the filename ending in 'r_cal.fit', and select it from the File menu. Now let's assign Red to this image

1. Select 'Color' from the menu
2. Select 'Color controls' from the menu
3. Select 'red' from the dropdown menu in the window that pops-up

When you select 'Color controls' in step two, another window pops-up. You can leave this window open and switch to another image.

Repeat this process for each of the files, assigning the corresponding color to each.

Combining Images to Create an RGB Image

Now that you have assigned a color to each image, you can combine them into an RGB image.

From the menu, select ‘Color’, ‘rgb mode’ and your display will change to show the full-color image:

Note the name of the file that’s active when you do this since we’ll need it in a few moments (check the File menu to see which of your images is the active one).

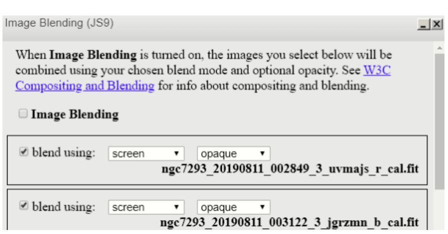
This is a pretty good image, considering we have done just a few minutes of work. Let’s try to improve the image by bringing in our Luminance FITS to improve the contrast and bring out some more detail.

Adding a Luminance Image To Your RGB Image

Open one of the files ending in ‘l_cal.fit’ in JS9. Measure the black point and adjust it as you did with the other images, and zoom to fit.

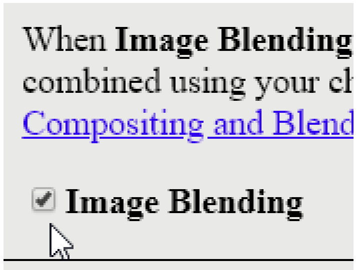
To bring in your Luminance image, you blend it with your color image and JS9 makes the process easy.

Make sure your color image is the active one (select it from the File menu) and from the menu, select ‘View’, ‘blending’. This will bring up a new window as shown:



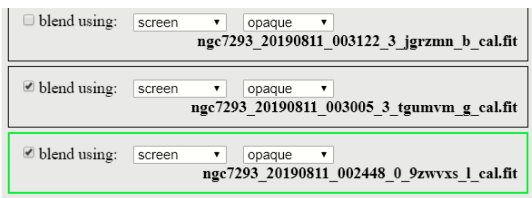
The active image is shown with a green box around it. There are checkmarks next to each filename, indicating that the image will be blended when we enable blending. For now, clear all of the checkmarks, except for those of the active image, and of the image ending in 'l_cal.fit'.

Click the 'Image Blending' option at the top of the list of files, as shown, to blend the images:



If your image looks blurry, chances are that the telescope moved during your mission while taking the image, so we'll have to align the image.

Make the luminance image the active one by clicking inside the box with the filename ending in 'l_cal.fit', as shown:



Aligning Your Images

We'll have to zoom in to be able to align the image more accurately, however, JS9 treats your images separately when you zoom. You'll have to remember to zoom in or out of each of your images separately.

From the menu, select 'Zoom', 'zoom 2'.

Make the combined RGB image the active one (you noted the filename above) by clicking in the box with its name in it. From the menu, select 'Zoom', 'zoom 2'.

Now we'll make the Luminance image the active one to align it. Make the luminance image the active one by clicking inside the box with the filename ending in 'l_cal.fit'

Using your mouse, right-click, hold the mouse button down, and drag to align the images. This will take some time to get it right, but try to align on bright stars.

Once you have the images aligned, zoom out to view your progress (remember to zoom out on your combined RGB image as well as the luminance image).

Adjusting the Bias Of Your Image

In my case, the image is a little washed out because the Luminance has brought in quite a bit of light color:

We can make a simple adjustment to fix this.

Make the Luminance image active (select it from the File menu). Select ‘Color’ from the menu, and adjust the ‘bias’ value in increments or decrements of 0.1, up or down, until your image looks better. Make small adjustments and press Enter to make the change on your image.

Adjusting the Gamma

Another adjustment you can make is the gamma. Gamma adjusts the luminance of your image and can sometimes bring out a lot more detail. To adjust the gamma, from the menu, select ‘View’, ‘Image Filters’. This brings up an image filters dialog that you can move out of the way of your image. Adjust the gamma by clicking the ‘gamma’ button, and adjust the slider left and right to manipulate your image. If you don’t like the effect, slide the slider all the way to the left to zero, or click ‘undo gamma’ at the bottom of the dialog box.

Note that sometimes the Gamma adjustment and other adjustments in the Image Filters menu don’t do anything. This seems to be a bug in JS9 and there’s no way to make it work once it stops working, except to reload the page (and lose your image) and start over again.
Saving Your Final Image

Once you have your image the way you like it, select File, Save, PNG and your file is downloaded by your browser using the name of the active file with a PNG extension.

This is the final version, as downloaded from JS9:

Next Steps

Next, I'll show you how to process a FITS file using DeepSkyStacker and Photopea.com.

Processing A FITS File Using DeepSkyStacker and Photopea.com

We're going to use DeepSkyStacker (DSS) and Photopea.com to create an LRGB image of Messier 20 using FITS files. The FITS files were captured using iTelescope.net, but they are similar to the files you would receive from Slooh's Canary One telescope.

Downloading the Sample Observation of M20

Use the following directions to download the observation of M 20:

1. Point your browser to RemoteAstrophotography.com
2. From the menu, select Downloads
3. From the downloads page, locate the link for "Messier 20 LRGB FITS – Book Sample.zip" (46Mb)
4. Download the sample file and unzip the contents to a convenient folder

Stack The Luminance Files

Use the following directions to register and stack the Luminance files:

1. Start DSS
2. From the set of links on the left, select *Open picture files*
3. Browse to the folder where you saved the FITS files from the ZIP file
4. Select all three Luminance files
5. From the left panel, select *Check all*
6. From the left panel, select *Stack checked pictures*
7. Click the *Recommended Settings* button and then click Ok
8. Click Ok to start stacking

9. When the process completes, from the left, select *Save picture to file*
10. Browse to the folder from step 3
11. Save the file as Lum.TIF (16 bits)
12. Exit DSS

Stack the Individual R, G, and B Files

Even though we have just one of each R, G, and B files, we still need to stack them to convert them from FITS to TIF. We'll again use DSS for this – follow the directions below:

1. Start DSS
2. From the set of links on the left, select *Open picture files*
3. Browse to the folder where you saved the FITS files from the ZIP file
4. Select the Red FITS file (it has Red in the name)
5. From the left panel, select *Check all*
6. From the left panel, select *Stack checked pictures*
7. Click the *Recommended Settings* button and then click Ok
8. Click Ok to start stacking
9. When the process completes, from the left, select *Save picture to file*
10. Browse to the folder from step 3
11. Save the file as Red.TIF (16 bits)
12. From the left panel, select *Clear List*
13. Answer No to the prompt to Save

Repeat the above steps for the blue and green files – ensure you use the correct file in step 4 and save it using the correct name (blue and green) in step 11.

You should now have four TIF files named Lum.tif, red.tif, green.tif, and blue.tif. We are now finished using DSS and must now switch to using Photopea.com.

The TIF files are ready to be combined to produce an LRGB composite image and we'll use Photopea.com for this (if you own Photoshop you can also follow these directions with slight changes). Use the following directions to create an LRGB composite image:

1. Point your browser to Photopea.com
2. From the menu, select *File – New*
3. In the *New Project* box, enter 1528 in the *Width* and *Height* boxes and click *Create*
4. From the menu, select *File – Open*
5. Browse to the folder where you saved the TIF files using DSS
6. Locate the red.tif file and double-click it
7. From the menu, select *Select – All*
8. From the menu, select *Edit – Copy*
9. Flip to New Project.psd
10. From the right side of the screen, select the *Channels* tab
11. Click the word Red so that the row is highlighted and there is an eye icon to the left
12. From the menu, select *Edit – Paste*
13. Repeat steps 6 to 12 for the blue file
14. Repeat steps 6 to 12 for the red file
15. At the top of the Channels listing, click the eye icon next to RGB

16. From the menu, select *Image – Adjustments – Levels*
17. There are three boxes with numbers in them across the bottom (0, 1, 255) – enter 3 into the middle box and click Ok
18. Click the *Layers* tab
19. From the menu, select *Layer – New – Layer*
20. From the menu, select *File – Open*
21. Open the Lum.tif file
22. From the menu, select *Image – Adjustments – Levels*
23. There are three boxes with numbers in them across the bottom (0, 1, 255) – enter 3 into the middle box and click Ok
24. From the menu, select *Select – All*
25. From the menu, select *Edit – Copy*
26. Flip to New Project.psd
27. Highlight Layer 1
28. From the menu, select *Edit – Paste*
29. Above the Layers panel there is the word *Normal* – click the downward arrow next to it
30. From the list that pops-up, select *Luminosity*
31. From the menu, select *Layer – Flatten Image*
32. From the menu, select *Image – Adjustments – Levels*
33. There are three boxes with numbers in them across the bottom (0, 1, 255) – enter 55 into the box on the left ,2.25 into the middle box and click Ok

You now have a composite LRGB image, congratulations. Save your image and we'll continue.

Next Steps

Now that you're comfortable with DeepSkyStacker and have some FITS data to experiment with, we're going to discuss understanding stacking and multi luminance processing.

Understanding Stacking and Multi Luminance Processing

When you read articles or watch videos about astronomical image processing, you'll often come across the term "stacking". This section is all about stacking.

As you learned earlier, the Slooh telescopes take a number of images and combine them to produce the final color result. The Slooh telescopes only 'see' in black and white and fundamentally understand only pixel intensity information, so we use a combination of filters and software to combine the black and white images in such a way that we get a color image.

Here's a listing of files produced by the Canary Four telescope for the M 31 target:

messier31_20190112_202542_0_ig6xno_l_cal.fit
messier31_20190112_202624_0_hm0mpa_r_cal.fit
messier31_20190112_202703_0_8da7mf_g_cal.fit
messier31_20190112_202739_0_vficbv_b_cal.fit

The filenames look confusing, but we're actually interested in the part near the end. Near the end of the filename you'll see things like "_l_", "_r_","_g_", and "_b_". Each letter represents the name of the filter that was in place in front of the telescope when the file was created. From this listing, you can see that all four filters were used.

If we were to open each file in something like Fitswork and view the header, you would also be able to see the exposure time and other details about the individual images. Here's part of the header for the L image:

Fits Header

```
SIMPLE  =                    T
BITPIX  =                   16 /8 unsigned int, 16 & 32 int, -32 & -64 real
NAXIS   =                    2 /number of axes
NAXIS1  =                 1119 /fastest changing axis
NAXIS2  =                  845 /next to fastest changing axis
BSCALE  =   1.0000000000000000 /physical = BZERO + BSCALE*array_value
BZERO   =   32768.000000000000 /physical = BZERO + BSCALE*array_value
DATE-OBS= '2019-01-12T20:24:47' /YYYY-MM-DDThh:mm:ss observation start, UT
EXPTIME =   50.000000000000000 /Exposure time in seconds
EXPOSURE=   50.000000000000000 /Exposure time in seconds
SET-TEMP=  -40.000000000000000 /CCD temperature setpoint in C
CCD-TEMP=  -37.343750000000000 /CCD temperature at start of exposure in C
```

The header includes a lot of information, including the exposure time of 50 seconds (the EXPTIME and EXPOSURE headings).

When creating astronomical images, the goal is to get the highest Signal to Noise ratio possible. What that means is our images are made up of two fundamental components: signal, which is the subject of the image itself, and noise, which is everything else we don't want.

In the case of an image of M 42, the signal is the image of all of the stars, the nebulosity, the colors of the dust lanes, and contrast information that makes up the image. The noise is artifacts introduced by the atmosphere, the camera, and even the telescope itself.

I mentioned in another section "Understanding Calibration" that Slooh calibrates images for us, so this is a great reduction in noise for all of our images and saves members a lot of work.

In creating PNG images for members to use, Slooh also saves us a lot of time by stacking and processing the images for us. However, Slooh tries to reach a good compromise between image quality and processing speed and so does not produce the best possible image for us. This is where processing, and as a result, stacking comes into play.

Stacking is the process whereby we layer images over each other to combine them into one final image. The stacking process takes into consideration the filter that was used to create the FITS file that's being stacked to introduce color information from the black and white images the CCD captures.

Stacking combines images using various methods including "Add" where the pixel intensity values of each image are simply added together, "Average" where the average value across images is taken, "Median" where the midpoint value is used, and more advanced combination including "Sigma Clipping" - a mathematical process that removes pixels outside of a calculated range. In the DSS example, we used "Average".

Understanding Long Exposure Time

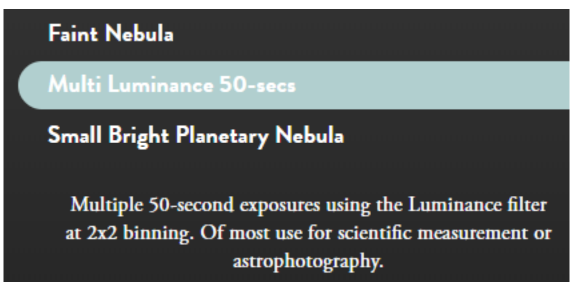
When you stack an image, you're essentially adding all of the exposure time of all the images together. So it's like taking one long exposure by combining the results of several shorter exposures. So why do we do this - why not take one long exposure and be done with it?

Recall earlier I said our goal is to get the highest Signal to Noise ratio possible. We want as much signal information as we can and as little noise as possible. The longer we look at an object, the more noise gets introduced - star tracking, wind, camera artifacts are just a few sources of noise in our images. We take shorter exposures to reduce the chance of noise and combine all those short images into one much longer exposure.

If you watch the Slooh missions, you'll often see members booking a number of sequential missions to the same object. What they're doing is getting many exposures of the object and they'll use that to combine them into one longer exposure by stacking. The image of the Helix Nebula I showed you earlier is made up of 32 individual exposures. Slooh members often get hundreds of exposures to make detailed images of things like faint or dark nebulas.

Understanding the Multi Luminance Processing Option

When you book a catalog or coordinate mission, you have the option of choosing a Processing Option. Two of the recipes at the very end of the listing are "Multi Luminance 20-secs" and "Multi Luminance 50-secs" as shown:



If you ever book a mission and take a look at the resulting PNG image, you'll wonder why anyone would ever use that Processing Option – here's a sample image that uses the multi luminance recipe:

The background is not very dark, there's a satellite streak going through the bottom left and the stars appear to be over exposed. Moreover, it's a monochrome image so all the stars look white.

The benefit of this type of processing option is in the FITS files. You get, as the description states, multiple exposures using the Luminance, or clear, filter instead of any color information.

This effectively extends the exposure time for really faint objects. The luminance filter captures the most light and I sometimes use multi luminance processing even when I'm working with color images to get more contrast. I might still capture the R, G, and B filters but also capture a bunch of multi luminance images just to bring out details in dust lanes for example.

Understanding Binning

Binning affects the resolution of your final image. Binning essentially reduces resolution in order to provide more light gathering capability. The total number of pixels is divided by the binning factor to essentially make each pixel bigger by trading off resolution.

For most processing presets, binning is set at 3×3 which means the resolution is essentially divided by three. So, for a telescope with 4096×4096 resolution, the binned resolution would be 1365×1365 at 3×3 binning. This also means that each pixel is represented by three physical pixels on the CCD camera, so you get more light gathering capability.

There are other presets that offer 2×2 binning (usually 'Globular Cluster', but it varies by telescope), and none that offer 1×1 binning, so bear in mind the binning factor of each preset when you're considering resolution.

Next Steps

The next sections discuss using GIMP, and an online editor called Photopea, to enhance your images.

Enhancing Images Using Photopea

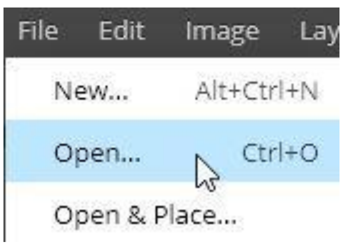
Photopea is a Photoshop clone that runs completely in your browser!

With free options like GIMP, why would you use Photopea? The main reason is that there's nothing to install on your system – Photopea runs in your browser. The other reason to use Photopea is compatibility. You can produce PSD files using Photopea and these files are completely compatible with the popular Photoshop application.

Start by visiting the Photopea site at https://photopea.com/

You can use either Firefox or Chrome. The creator of Photopea says Firefox does better with larger images since it can take advantage of all of your computer's memory whereas Chrome is more limited. The functionality of Photopea is identical between the two browsers.

Let's start by opening an image we created previously using either JS9. Select File – Open to open the image:



In this example, I'm working with an image of the Trifid Nebula which has dark area, bright areas, and regions of nebulosity.

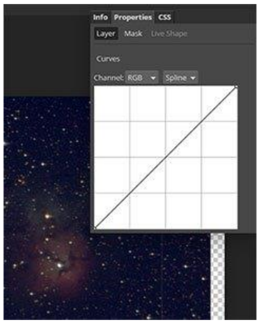
Curves Adjustment and Layers

We want to make the background darker while retaining the nebula. A curves adjustment is good for this purpose.

The Curves adjustment is a very powerful tool because you can change how the intensities of pixels are mapped to the final image. It's great for preserving details while boosting contrast.

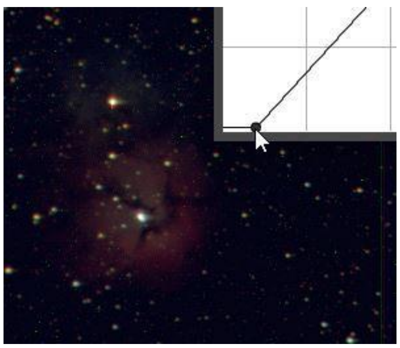
We'll use an approach called non-destructive editing where I have you create layers for the adjustments. Doing this leaves the original image intact yet allows you to see what your changes will look like.

Start by selecting Layer – New Adjustment Layer – Curves. Your screen will look similar to this:

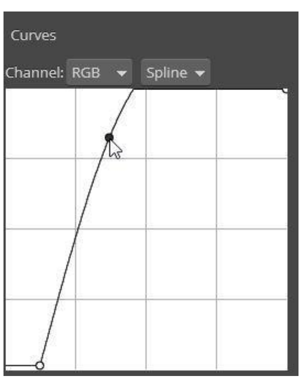


The diagonal line basically says that Photopea should map all pixels from black to white, one to one, so you don't yet see any changes in the image.

Drag the dot on the bottom left of the window a little to the right: the background becomes darker as you do this. You are essentially adjusting black pixels here, making them more prominent.

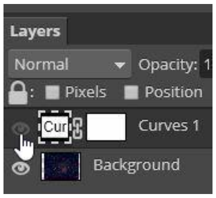


Next, make the pixels that make up the nebula more prominent while slightly affecting the background adjustment you made. Put your mouse in the very center of the diagonal line, click and drag to the point shown in the following screenshot:



As you do this, the nebula becomes more prominent and the background becomes a little lighter. You can move that first dot at the bottom left a little more to the right to make the background darker again. Note the effect it has on the nebula – you want to achieve a good balance between making the nebula more prominent and the darker background.

Click the eye next to the curves layer as shown, to turn off this layer:



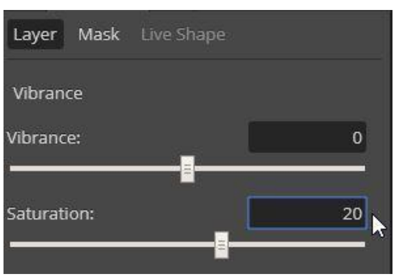
By switching the layer off, you can see that the original image is still intact and your adjustment resides on a separate layer. Click the eye again to turn the layer back on.

Let's boost the colors in the image a little using a Vibrance adjustment.

Adjusting Vibrance

Select Layer – New Adjustment Layer – Vibrance to add the new layer.

In the properties window, change the Saturation value to 20 – you can either drag the pointer over to the right or you can just enter the value. Toggle the layer off and on to see the effect – it's pretty subtle but it makes a difference.



Next, let's reduce the noise in the image.

Click View – Zoom In to zoom into the image a little. You can also zoom in and out using your mouse wheel – hold down CTRL and ALT and scroll your mouse wheel to zoom in and out.

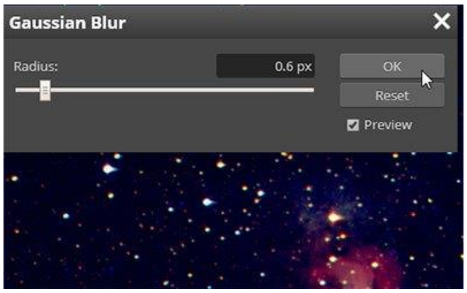
Applying a Gaussian Blur to Reduce Noise

You'll notice a lot of green, blue, and red pixels in the image – this is noise from the camera that's attached to the telescope. Unlike Slooh's cameras, which are cooled to about -30 Celsius, the MicroObservatory's cameras, which I used to capture this image, are not cooled and their temperature varies with the ambient temperature outside, which contributes to noise in your final images.

We can reduce the noise a little by making another adjustment. Make sure the image layer is active – click the bottom layer in the stack of layers (it's labeled Background).

Select Filter – Blur – Gaussian Blur to bring up a new window. The change you make using this command will change the image.

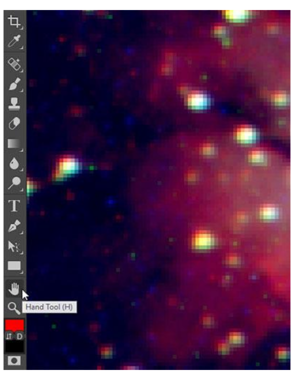
Select a pixel size of 0.6 px and toggle the Preview checkbox to see the dramatic difference it makes. Note as well that the blur also affects the detail in the nebula, so this value is a good balance between reducing noise and retaining detail.



Click Ok to commit the change.

Using the Spot Healing Tool to Enhance Your Image

Zoom in more and use the Hand Tool (highlighted in the screenshot below) to move the image around so it looks something like what you see in the screenshot:

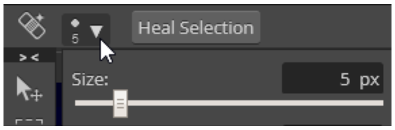


You'll notice that the green, blue, and red pixels are still present in the nebula and surrounding areas. The Gaussian blur did not completely get rid of those extra pixels. We'll use the Spot Healing tool to remove the extra pixels from the nebula to make it look nicer.

The Spot Healing tool is a smart tool in that it is a content-aware paintbrush. What it does is it looks at the surrounding pixels and brushes over the area you select using those nearby pixels, which effectively removes defects without it looking like you painted over them.

Hover your mouse over the area on the left side of your screen, as shown on the screenshot and select Spot Healing Brush Tool.

Next, click the area at the top left of the screen, as shown in the screenshot below and enter 5px in the Size box.



What we're doing here is adjusting the size of the brush. You can also increase and decrease the brush size by pressing the square bracket key on your keyboard (the bracket on the left makes the brush smaller and the bracket on the right makes it bigger).

Find one of the extra pixels, hover your mouse over it and click. The brush evaluates the pixels around it and uses the same pattern to draw over the pixels you selected. Some areas might be a little more stubborn and won't disappear with just a click. In that case, slightly drag your mouse to paint over the pixels. When you drag your mouse, the tool evaluates more pixels to use to paint over the area you selected. If you find you want to undo something, press CTRL-Z to undo your last action.

You could go on editing for quite a while, but just stick to the nebula itself for this exercise.

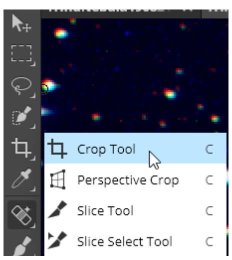
Zoom out again and check your progress – your nebula should look much better now.

Save your work now. Click File – Save As PSD to save in Photoshop compatible format.

Cropping Your Image

With the image zoomed out, you can see there are areas at the bottom that don't look good at all, so we'll crop the image to exclude those areas. We can make this change on the image itself since we have already saved your work, so in case you don't like the result, you can just load the image you saved.

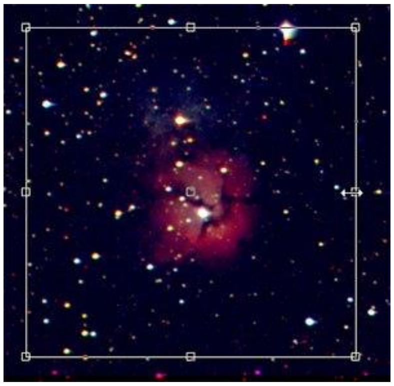
Hover your mouse on the left side of the screen, as shown below, and select Crop Tool:



At the top of the screen, find where it says Free and change it to Fixed Ratio, and enter 1 in the W and H fields. What we're going to do is select an area of the image that's a square.

You'll see a square show up around the edges of your image – zoom out if you don't see it. Click the handle on the left (the small square) and drag it toward the center of the image. You'll see the square getting smaller as you do this.

Move the square and resize it so that it looks something like this:



Once you have it, press Enter on your keyboard to commit the change.

Now save this image as a PNG or JPG – this is your final image.

I discuss using Photopea on this book's companion website at RemoteAstrophotography.com.

Next Steps

Now that you understand GIMP and Photopea, and the powerful tools they offer, and know how to use them, it's time to start editing your own photos from Slooh!

You're in a great position now to start capturing all kinds of images and perhaps do your own research!

The next chapter discusses using AstroImageJ to take advanced measurements from your images to gain more insight into them and the information they hold.

If you're interested, I have included some more details about my own workflows using TheSkyX, Photoshop, and MaxIM DL. I also discuss some other activities I get into that are not within the realm of Slooh, but could easily be if you wanted to try: exoplanet research

I also discuss some of my background and how I came to Slooh and explain the tools and workflows I used to create this book.

Thank you for reading and I look forward to interacting with you directly or via the community at Slooh. My name at Slooh is ErikW.2014 and you can always reach me by email at erik.westermann@gmail.com.

If you like this book, please write a review and post it on your favorite astronomy forum.

Keep in touch by visiting http://RemoteAstrophotography.com

Learn More About Astronomy

You can learn more about the things in the sky with my other free book, Introduction To The Cosmos.

Introduction To The Cosmos is for beginner to intermediate astronomers that want to learn more about the objects in the sky, including the lifetimes of stars, galaxies, nebulae, and much more.

Download your free copy of Introduction To the Cosmos here:

http://IntroductionToTheCosmos.com/

Online Resources

Companion Website:
http://RemoteAstrophotography.com

An article about RGB color model:
https://en.wikipedia.org/wiki/RGB_color_model

An article about Color depth:
https://en.wikipedia.org/wiki/Color_depth

Telescopius:
https://telescopius.com/

Astrobin:
https://astrobin.com

Seiichi Yoshida's Home Page (weekly information about bright comets):
http://aerith.net/index.html

MicroObservatory – a site where you can control a robotic telescope for free:
http://mo-www.harvard.edu/OWN/

DIY Planet Search – allows you to schedule exoplanet transit observations with the MicroObservatory:
https://www.cfa.harvard.edu/smgphp/otherworlds/OE/index.html

Exoplanet Hunting using AstroImageJ:
http://astrodennis.com/

Part V: Appendix

Photometry, Stacking and Processing Using AstroImageJ

In astronomy, photometry is the measurement of the brightness of stars and other celestial objects in an image. These measurements can provide information about the object's structure, temperature, distance, age, etc. The measurements can also provide information about the quality of the overall image and can be used in time-based analysis to detect things like exoplanet transits and measure the variability of variable stars. Personally, I use the measurements to find faint objects in my images and to determine the quality of the images I use before I share them with others.

In this chapter I walk you through basic photometry, stacking, color image processing, and plate solving.

AstroImageJ is derived from the popular imaging application called ImageJ, which has enjoyed broad use in various fields including medical imaging. AstroImageJ is used by undergraduate students in astronomy as well as professional astronomers. Its goal is to be usable by a broad range of users including amateur astronomers.

AstroImageJ is available across platforms so you can use it on Windows, Mac, and Linux. AstroImageJ is in the public domain and uses publicly available services like Nova.Astrometry.Net for plate solving, so there's no cost involved.

AstroImageJ is ideally suited for performing measurements on your images. While you can use it to produce your final color images, the process to do so is involved and you might get better and faster results in other applications like Fitswork or MaxIM DL.

I assume that you have already installed AstroImageJ. If not, go to the AstroImageJ in software installation before continuing.

The interface to AstroImageJ is not very friendly as it assumes you know what you're doing. The menus are kind of confusing as well. Once you open an image, you're presented with a window that has several menu options, but the smaller AstroImageJ window also stays open. The menu in that smaller window is also usable on your image, so you might have to switch back and forth between the two, depending on what you're doing. The nice thing about AstroImageJ is that it opens a new window whenever you do something significant, so you can always switch back to your original image since it will still be open in the background.

Although AstroImageJ is used in the detection of exoplanets, I don't show you how to do that here for a couple of reasons:

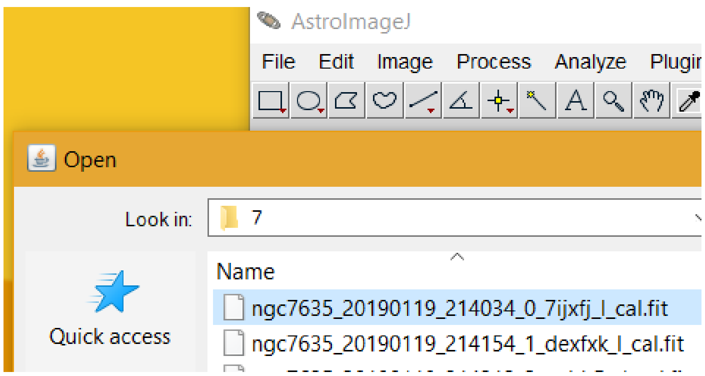
1. You need a lot of observations to detect an exoplanet transit. You typically need observations every three to five minutes during a window of about 90 minutes spanning before, during, and after the transit. While I have that data, I cannot share it with you because it's quite a bit, but I do explain how to get the data in the next chapter on Exoplanet Hunting if you care to try it.
2. AstroImageJ requires all FITS files to be plate solved. While the plate solving process is completely automatic it can be time-consuming because you use a free and publicly available plate solving service. I explain a way around that at the end of this chapter in case you want to try exoplanet hunting on your own.

The process of detecting an exoplanet transit using AstroImageJ is well-documented, so there's really no need to repeat it here – I provide you with a resource for this in the "Online Resources" section. The processes I show you here help build the skills you'll need during exoplanet hunting using AstroImageJ.

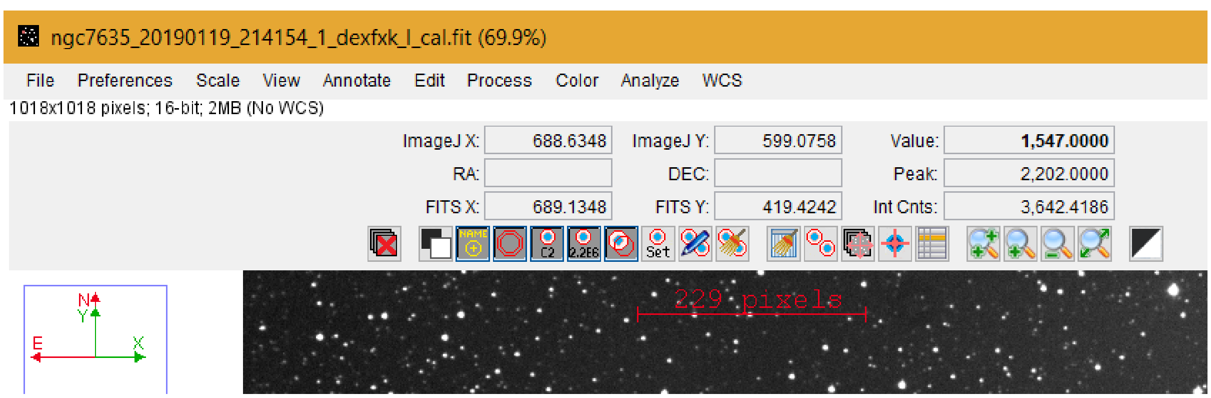
Basic Photometry and Understanding the Results

You'll need some FITS images to work with in this chapter, so you can use the ones you downloaded before from this book's companion website or perhaps use some FITS files you downloaded from Slooh. In this section, I use files I downloaded from Slooh.

Start by opening an image - select File - Open and select a file as shown:



In this case, I'm opening an image of NGC 7635 and a new window appears, as shown:



This new second window you now see contains the image, and note that the first smaller AstroImageJ window is still open in the background. You'll need that smaller window later, so leave it open.

Also, when you take certain actions, AstroImageJ will open a new window with the result of those actions so you don't have to worry about undoing anything. If you don't like the result, simply close the window and you'll be returned to your original image.

To ensure you can actually see the picture you opened, select Scale - "auto brightness & contrast". This setting analyzes the image and ensures that its not too light or dark for you to be able to see it.

Move your pointer around the screen and note how the numbers in the boxes at the top of the screen change. You'll notice that the values for ImajeJ X,ImajeJ Y, Value, Peak and others change as you move the pointer around. This is actually the most basic form of photometry because AstroImageJ is providing you measurements from the image as you move your pointer.

The Value box lists the Value of the pixels under the pointer. Move your pointer over a bright star and chances are the Value will be quite large. Move the pointer over to a darker region and the value will be, comparatively, smaller. The Value is the pixel value under the pointer and varies between zero and some upper limit determined by the file's fidelity. For a 32-bit file, the upper limit of Value is 2,147,483,647 even though the camera might max out at some lower value.

The RA and DEC boxes show you the Right Ascension and Declination of your pointer on the image, so you would know the coordinates of where you are pointing, as shown:

ImageJ X:	237.0959	ImageJ Y:	231.5498	Value:	**767.0000**
RA:	09:20:55.486	DEC:	-31:12:29.30	Peak:	1,130.0000
FITS X:	237.5959	FITS Y:	268.9502	Int Cnts:	13,775.2803

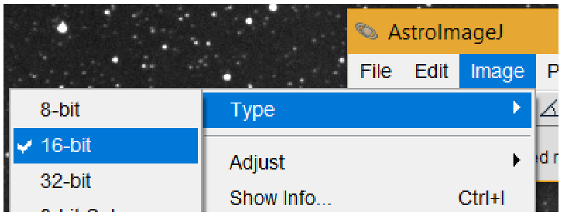
Note that the RA and DEC boxes on your screen are probably blank because the image needs to be "plate solved" first. "Plate solving" is a process whereby a given image is analyzed against a catalog of stars to figure out what stars are in the photo, along with other information about the photo (like it's scale). Plate solving makes it easier for you to locate things on your image much more quickly if you know the coordinates you're looking for.

You can get AstroImageJ to plate solve your images using the free nova.astrometry.net service - I show you how to do that later in this chapter under the heading "Plate Solving Using AstroImageJ".

You can zoom in and out using your mouse wheel and you can move the image around by clicking and dragging.

Right now, your pointer is a simple circle and the measurements you see in the boxes at the top of the screen are limited to the area immediately under the pointer. The photometry we've done so far is interesting enough in that we now know the approximate range of our image - we can measure the dark and light areas to get an idea of the range of pixel values.

Depending on the type of file you have opened, you can figure out what the maximum Value might be, so you can know when the pixels in a region have been maxed out and are therefore saturated. In the smaller AstroImageJ window, select "Image" - "Type" and check which option is already selected for you, as shown:



In this case, the image is a 16-bit image. So, if we come across an area that has a value of 65,535 (the maximum value of a 16-bit integer), we know that the CCD collected the maximum amount of light it can collect, so you can say those pixels are saturated. Saturated pixels are not useful when doing photometry because the CCD camera has collected the maximum amount of light it can collect.

Saturated pixels are usually, but not always, an indication that your image was over-exposed. Maybe you selected a Multi Luminance 50 processing recipe and now have saturated stars - this could be an indication to try the Multi Luminance 20 processing recipe instead.

Configuring The Aperture Setting

The measurements we have so far give us details about just what's under the pointer. There are times where you want to be more precise to include a larger star and some background for example. For example, take a look at your image and chances are that you have larger and smaller stars. We'd like to be able to take measurements of particular stars and gain more insight into them.

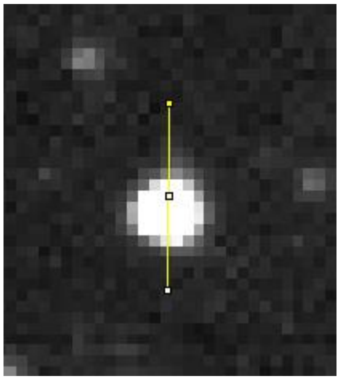
Click the fourth icon from the left, it says "toggle display of aperture sky background regions" when you hover your pointer over it.

Your mouse pointer now becomes three circles. These three circles indicate special areas AstroImageJ will use to measure the pixels on your image. The size of these three circles is really important and there are functions in AstroImageJ that set these for you so you can use them later.

Let's set up these circles so that they're the right size for the stars we want to measure.

Start by zooming into your image and find a region having a couple of different sized stars in it. You don't have to zoom in very far - you can see how far you have zoomed in by looking at the title bar - it lists the zoom percentage in brackets after the filename.

Hold down the ALT key on your keyboard, and click and drag through any reasonably bright star as shown:



You might have to try a couple of times to get it right. So you hold down ALT, then click and drag through the star and then release the ALT and mouse button.

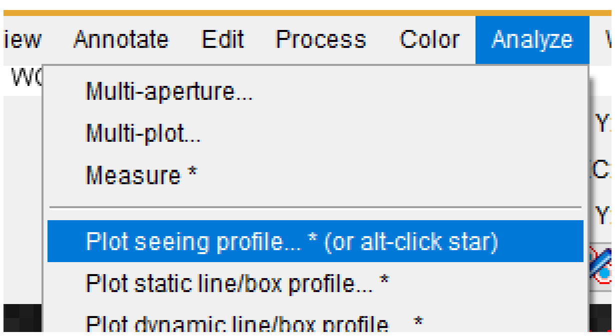
Try to select a star that's on its own with no other stars that are too close by.

A small window might appear when you release the buttons - you can just close it since we don't need the information it displays.

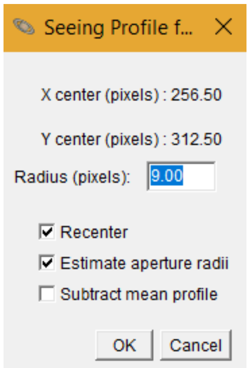
Your screen should look something like what I show you in the preceding screenshot of the star.

AstroImageJ saves each line you draw so before continuing, if you have tried a number of times, clear all of your previous tries before you continue and ensure you have only one star selected. You can clear all your previous tries by clicking the tenth icon from the left - it says "clear apertures and annotations from overlay" when you hover your pointer over it.

Now that you have a star selected, from the menu, select "Analyze" - "Plot seeing profile" as shown:

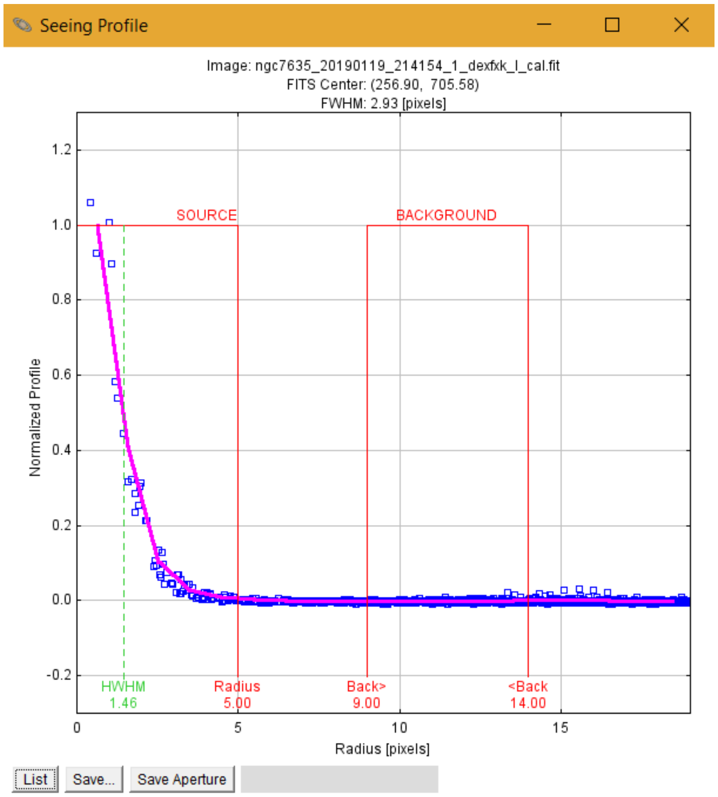


A new small window comes up as shown:



The number in the Radius field might be different - you can just select Ok to continue.

A new window opens as shown:

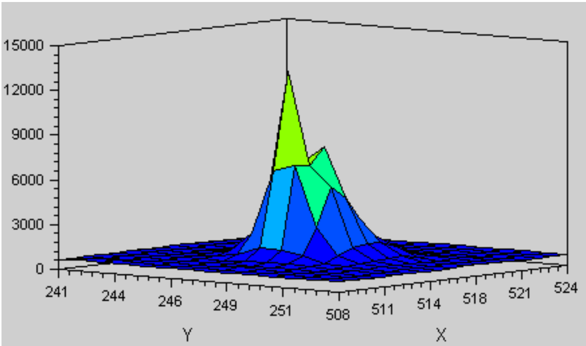


This is the "Seeing Profile" window and shows us some interesting information about the selected star.

The chart you see is divided into two sections, "Source" and "Background" with a curved line starting from the left. The curved line is the chart of pixel values coming off the star. The chart starts at the center of the star on the left and plots pixel values towards the edge of the star as you move to the right on the graph. The Y axis values are what are referred to as 'normalized' values and range between 0 and 1.2 - they're not the actual pixel values from the image.

From this, you can see that the star has a small number of pixels at its peak, that quickly drop off as you reach the edges. From there, the pixel values drop off into the background noise of the image.

Here's a 3-D plot of a star that I took using MaxIM DL:



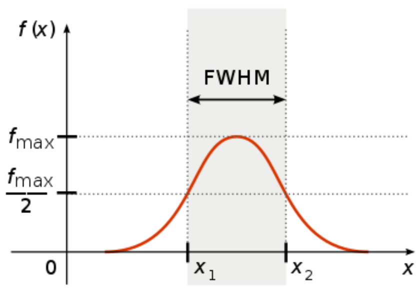
From the plot, you can see that there's some variation in the star before it reaches its peak - the large green cone. You probably wouldn't be able to detect this variation on the image which is why a chart like this can come in handy. The chart AstroImageJ produced for you takes this variation into consideration when it plots the points. This variation is also important for a calculation it does, which I explain next.

At the top of the chart are three lines:

- The filename
- The coordinates of the center of the chart
- FWHM value

This last value is important as it tells us using a single number about the quality of the seeing conditions of this star when this image was taken.

FWHM is actually a mathematical term which expands to Full Width, Half Maximum. It's related to a graph you can draw of pixel values that represent a star, called a Gaussian Curve. Here's what a Gaussian Curve looks like:



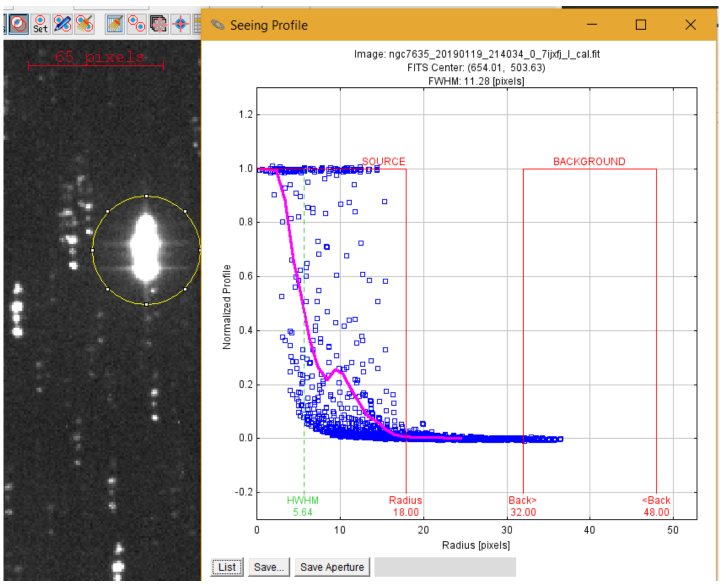
(image credit: https://en.wikipedia.org/wiki/Full_width_at_half_maximum)

You'll notice that the chart has a resemblance to the 3-D plot of the star I showed you a little earlier.

The FWHM is taken at the highest part of the Gaussian curve. In the chart, the highest part of the curve is above fmax/2 and the FWHM is shown in gray.

The FWHM represents the quality of seeing conditions. The lower this value, the better the seeing conditions. The FWHM can be as low as 0.4 for really big telescopes and can be as small as 0.05 for the Hubble Space Telescope! Also note that the FWHM can be quite high when you're working with really faint objects and this is normal since the object itself will be just above the noise in your image.

Just for a test, I wanted to see how bad I could get the FWHM with an image that was taken in heavy wind. I took a measurement from a star that had become duplicated because the telescope moved during the observation and this is what I came up with:



As you can see from the chart, the star's maximum value is saturated and full of data points. Also note that there's a bump in the "Source" area of the chart representing one of the duplicated stars and there's quite a bit of noise in the "Source" region. The FWHM is calculated at a whopping 11.28, which is understandable, given the conditions.

This chart window is more than informational, it can also set the aperture for you mouse pointer making subsequent measurements easier!

The chart has some numbers going along the bottom in red. The numbers represent the suggested size of the aperture to make subsequent measurements easier. The size is given in pixels and, in the original chart I showed you, it's suggested that the inner ring be 5 pixels wide, the inner radius be about 9 pixels wide and the outer radius be about 14 pixels wide.

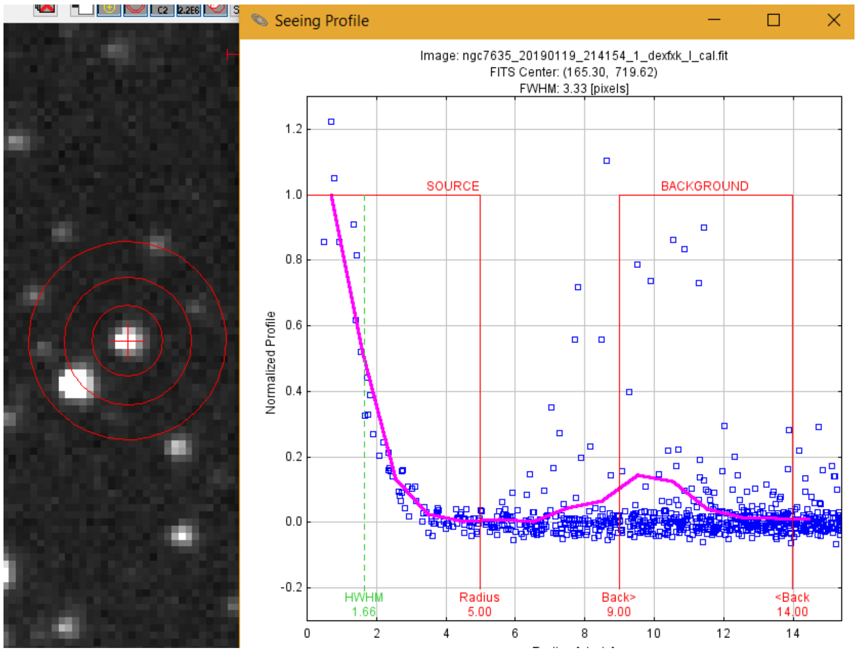
Click the "Save Aperture" button at the bottom of the chart and close the graph window. Although nothing seems to happen, if you move your mouse over the image you'll notice a change.

You may notice now that the rings have changed size to the ones suggested by the graph plot.

Close the chart and pick another star that's on its own and is roughly the same size as the last star. This time, press ALT on your keyboard and just click to bring up the graph. You may notice that the graph has changed a little and the value for FWHM has changed.

So, all this is good news so far because your stars match the expected curve and the values are good. You'll notice that I have been asking you to select stars that are relatively alone while taking these measurements because I wanted to get good results for this walkthrough.

Let's see what happens when we pick a star that's close to another one, as shown:



In this case, the outer ring contains a couple of stars and has affected the result we got. If you look at the chart, you'll see a bump in the background range - that's where the other stars are. You'll also see the extra points in the chart in the background.

Also, the FWHM value has jumped quite a bit to 3.33 because the quality of our star has gone down since we now include another star in the background.

This is why the size of that ring is so important. You need to select a size for the ring so that most of your stars fit into it and give you the correct measurements. This setting affects all of your measurements including your hunt for exoplanets, so get used to adjusting the ring size accurately.

Use the process I showed you earlier to let AstroImageJ pick the size for you - just ensure you pick the right stars in your image.

You can set the size of the aperture directly by clicking the eighth button in the toolbar - it says "change aperture settings" when you hover your mouse over it. The settings in that window are pretty involved and well documented, however, I typically only vary the first three options.

So far we've only looked at one image in AstroImageJ and while that's interesting, it limits us to only one exposure. We can also stack the results of multiple exposures - that's the topic of the next section.

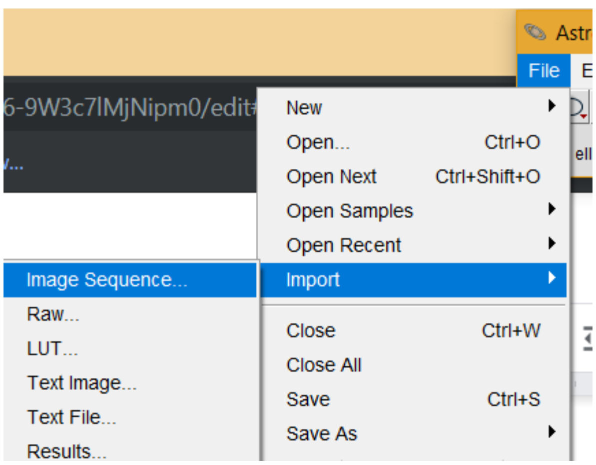
Stacking In AstroImageJ

As I mentioned earlier in this book, we stack multiple exposures of something to get an overall longer exposure with the goal of improving the Signal to Noise Ratio. As a result, stacking images is common and AstroImageJ supports stacking although looking through the menus, stacking is not apparent.

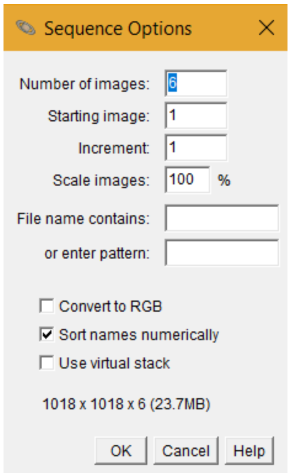
A stack of images in AstroImageJ is called an "Image Sequence" and you start by importing it into working memory. Once in memory, you stack the images into one resulting image using a "Z Projection".

Before you begin, you need to make sure that all of the images you want to be part of your stack are in a folder on their own. There shouldn't be any other images or files in the folder you want AstroImageJ to import to make the process simpler. Once you get more comfortable with AstroImageJ, you can set it to look at specific files to make the process easier but for now just make sure the files are isolated in a folder on their own.

From the AstroImageJ menu, select "File" - "Import" - "Image Sequence" as shown:



From there you'll see the standard Windows file selection dialog box. Select just one file and click Open to reveal the following window:



The important parameter in this window is "Number of images" - AstroImageJ tries its best to identify the images in the stack and might include other files if they are present in your folder. Later, you could fill in these parameters to narrow down which files AstroImageJ operates on. For now, click Ok.

In addition, make sure the option for "Use virtual stack" is unchecked. A "virtual stack" is backed by disk space and the files in the virtual stack cannot be changed. When you uncheck this option, you're telling AstroImageJ to load all of the images in the stack into memory. Since this is a small number of images, this shouldn't be a problem. If you run into problems with memory, click the "Use virtual stack" option.

You'll end up at a screen you have seen before when you had the other image open. The difference this time is that there's a scroll bar along the bottom of the screen where you can scroll across and see each member of the stack.

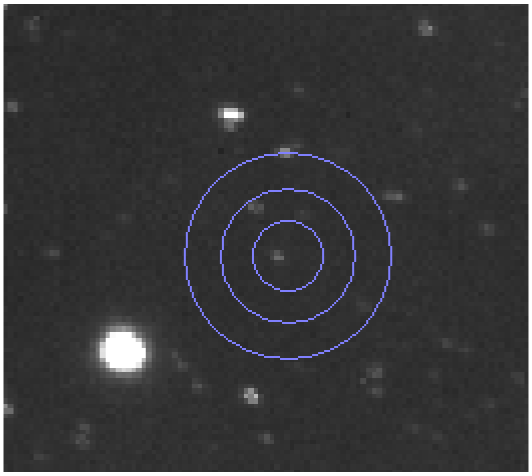
So how do we stack these images into one image where we can take measurements? A stack in AstroImageJ as referred to as a "Z Projection" - the term is derived from math.

But before we do the "Z Projection", we need to ensure that all of the images in our stack are aligned. If images in the stack are out of alignment, you'll end up with duplicate stars and have other artifacts in your image. Misalignment happens when the telescope moves as it is acquiring your image, or there's a tracking error, or other possible reasons.

Aligning Your Stack in AstroImageJ

We're going to use the Aperture tool we used earlier to do basic photometry on the image, so if you haven't already gone through that section (Basic Photometry and Understanding The Results), please do that now since you'll be using the skill you developed there to align the stack.

With the images open, ensure that the fourth button from the left is selected - it says “toggle display of aperture sky background regions” when you hover your mouse pointer over it. Your pointer should look something like this when you move it over your image, when the option is enabled:

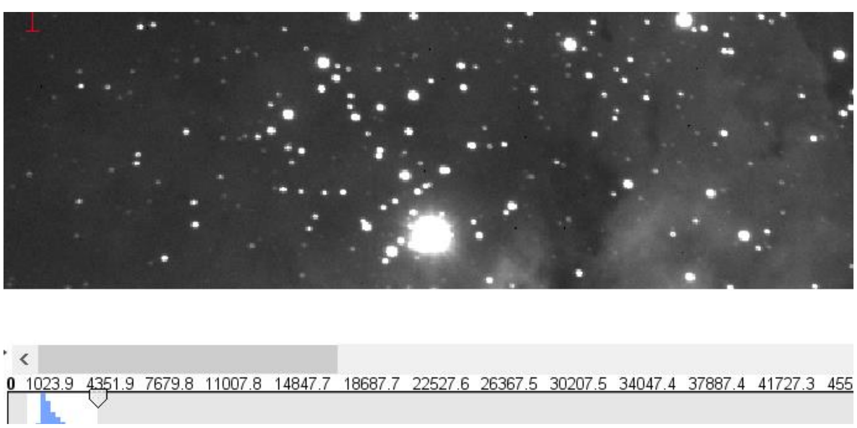


To align your image, you select some stars that are visible in each slice of your stack, which the alignment tool will use to align your final image.

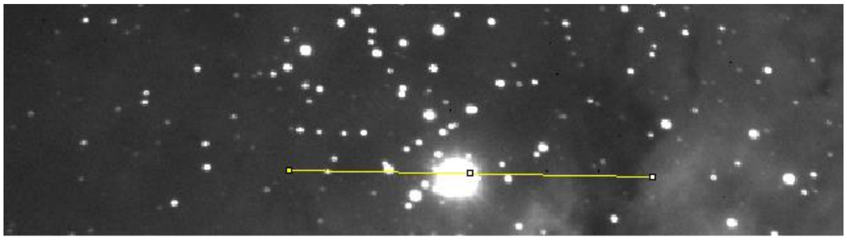
You can ‘cheat’ though if you have a large galaxy or other large region in that’s part of your image: you can select just that one part of the image and let the alignment tool do its work based on that. It saves you from having to select multiple stars.

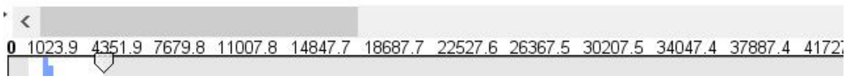
I have an image of NGC 3372 which includes a bright region that is present in all of the slices of my stack, so I’ll use that whole region to align my image.

As you did in the preceding section, you’re going to get AstroImageJ to select the size of the aperture for you. Start by bringing the area you’re going to use onto the screen - drag and zoom as necessary. This is what the bottom of my screen looks like:



Now press ALT on your keyboard, click and drag through the galaxy or area you want to use to align the image (it can be quite large), and release the mouse button and ALT key. My screen looks like the following when I finished:

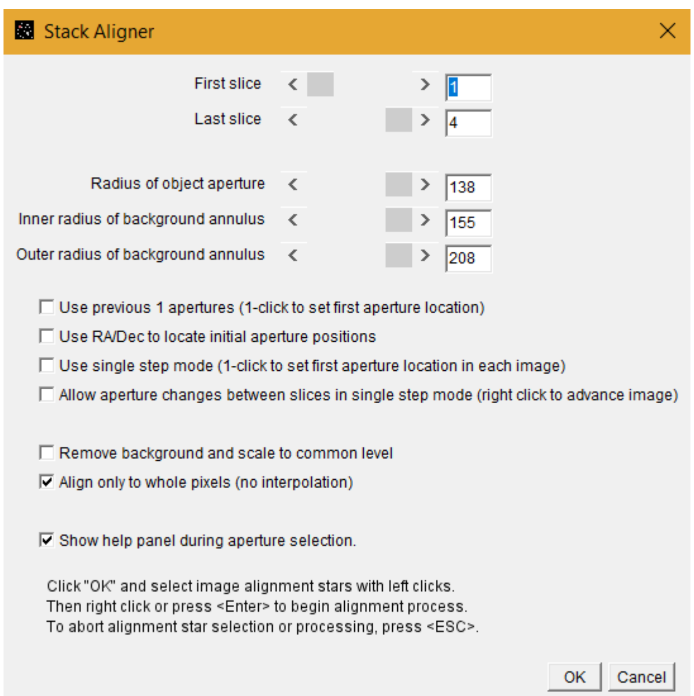




From the menu, select "Analyze" - "Plot seeing profile, and click Ok on the small window that pops-up. You'll see the "Seeing Profile" graph show up on your screen as you did in the preceding section. Don't be too concerned with the off-the-chart FWHM or the plot on the graph. What we're interested in is the result of clicking the "Save Aperture" button.

So go ahead and click the "Save Aperture" button, and close the "Seeing Profile" graph. We now have the aperture setup to use the region to align our image.

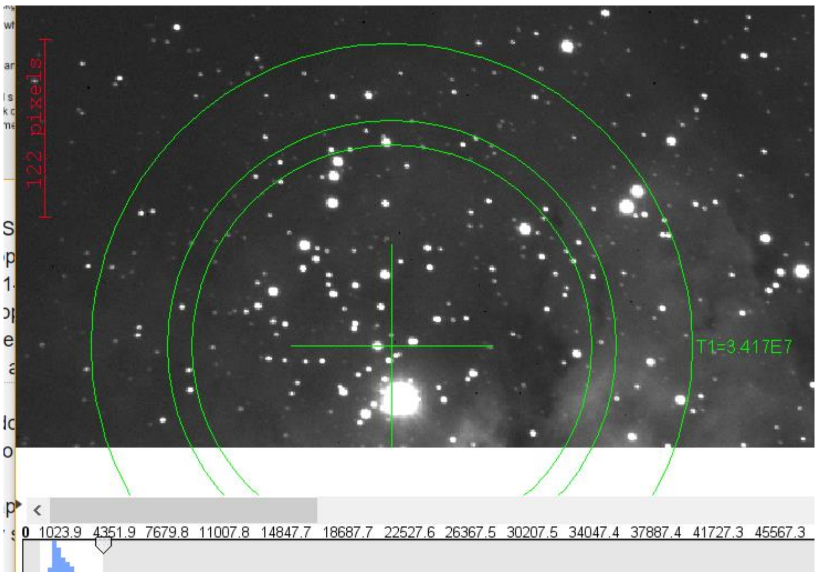
Click the 13th button from the left - it says "align stack using apertures" when you hover your mouse over it. A new window pops-up:



This is the "Stack Aligner" window and it is asking you select several options. The most important option here is the first checkbox that, on this screenshot, says "Use previous 1 apertures (1-click to set first aperture location)". Make sure this option is *deselected*. If you select this option, AstroImageJ remembers your previous aperture selections which can lead you to some very confusing results. Leave the other options at their defaults, as shown in the screenshot and click Ok.

A new window called "Stack Aligner Help" pops up with instructions on how to place the aperture - you can ignore the instructions for now.

Place the aperture on the galaxy or whatever you selected earlier and left-click your mouse button - my screen looks like this now:



You'll note that my aperture went off the edge of the screen and that's fine for this process.

Now that you have selected the region, press Enter on your keyboard to begin the alignment process.

Your screen will change a little as the aligner works and you'll end up at the screen with your image in it again. You can check the results of the alignment by dragging the bar that's located at the bottom of the image.

If the alignment fails, your image will move in the window as you drag the bar across. If this happens, repeat the process, starting at the point where you import the image sequence, but this time select a few stars. Try using the procedure I showed you to adjust the aperture and try aligning. Select three to four stars that are roughly the same size and are in each slice of the stack (refer to the section Basic Photometry and Understanding the Results for details).

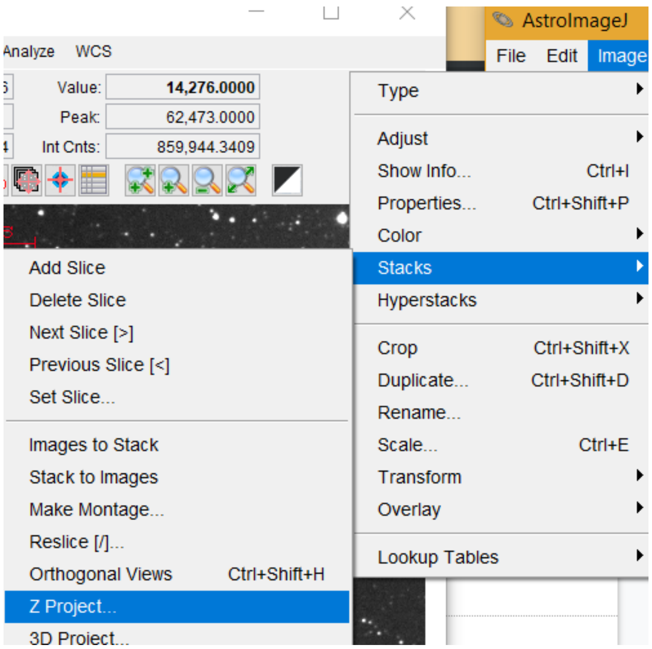
If you're still having trouble aligning your image, the aperture might be too small and your image might be moving around too much. AstroImageJ can align your images as long as the image doesn't move beyond the size of one aperture. If your image moves around a lot, try to increase the size of each of the members of the aperture by 10 pixels and try to align again.

Now that you have the stack aligned, you're ready to "Z Project" the slices into one final image.

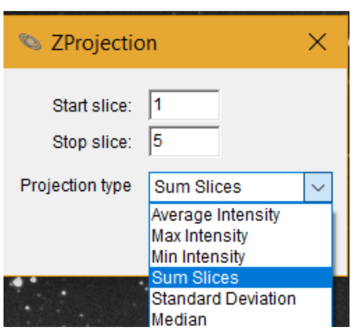
Projecting Members of the Stack into a Final Image

This section assumes you have followed the directions in the preceding section to align the images in a stack. If you haven't already done that, please skip back one section and follow the directions there since the directions here pick up where we left off.

In the smaller AstroImageJ window, select "Image" - "Stacks" - "Z Project", as shown:



Another window comes up, as shown:



This window is asking you to confirm the number of "slices" (images that are part of the stack) and to select the "Projection type".

A "Projection type" is the type of mathematical operation you want to perform on the pixel values when you combine the image and there are several types of operations. Operations include "Average intensity", "Max intensity", "Sum slices", "Median", and others. The one you select depends on what information you want to derive from the stacked image and effects how the final image appears on your screen. The “Median” projection type will help to get rid of outliers like satellite trails in your image at the cost of losing some details.

As a result, the selection you make here can be important if you’re taking precise measurements, so you might have to experiment a little. You can always project the stack again if you don’t like the result.

For now, let’s pick “Sum slices” since we’d like to get the total value of all of the members of the stack.

If you mouse over various stars, you’ll notice that their Values have increased quite a bit compared to the original image. This is because you’re now looking at the sum of all the slices in your stack.

You can take measurements of the various stars in this image the same way you did before. Try selecting a new aperture size with the help of the “Plot seeing profile” analysis option.

The next section covers how to convert an image stack into a color image. You can use the resulting image in GIMP or any other image processing application to further enhance it.

Processing A Color Image in AstroImageJ

AstroImageJ can create a color image for you using your stack. The process involves importing the image sequence, aligning the stack, and then composing an RGB image. I show you how to get results quickly and explain how you can add more control to the overall process for images with a large range.

Before we begin, remember that Slooh produces four types of FITS files for us:

- L - Luminance filter
- R- Red filter
- G - Green filter
- B - Blue filter

Note that this is true, except for Canary Three, which always produces a FITS file containing a color image and is named using the letter M instead of one of the preceding color filter names.

Also, be aware that this process does not work for missions where you use the Multi Luminance processing recipe. Recall that the Multi Luminance processing recipe produces only grayscale images using the Luminance filter only, so you won’t be able to produce a color image from that.

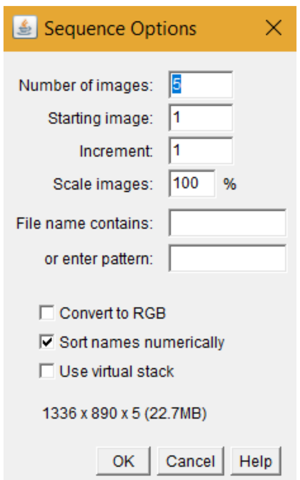
AstroImageJ does not currently support Luminance images directly. This means that you can only use the R, G, and B FITS image to produce your RGB image. I show you a way to incorporate your Luminance images anyway to get the most fidelity into your final image. This process involves moving files around, but all of the steps produce a good final image.

An overview of the process of producing a color image is as follows (I’ll explain each of these steps in detail as we go along):

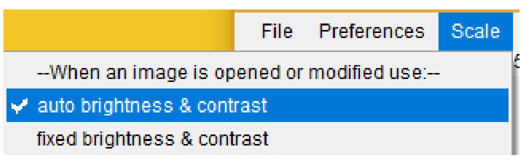
1. Acquire all of the FITS images for your mission
2. Align all of the images and save them
3. Separate your images so that the Luminance files are separated from the R, G, and B FITS files
4. Load the sequence of R, G, and B FITS files
5. Compose an RGB Image
6. Add the Luminance files to RGB image
7. Save the resulting image

Start by acquiring all of the FITS files from a mission - keep all the files in a folder on their own.

Next, select "File" - "Import" - "Image Sequence" and select the first file to import. On the second window that comes up, ensure that "Use virtual stack" is unchecked, as shown:



Before continuing, ensure that you select "auto brightness & contrast" under the "Scale" menu as shown:



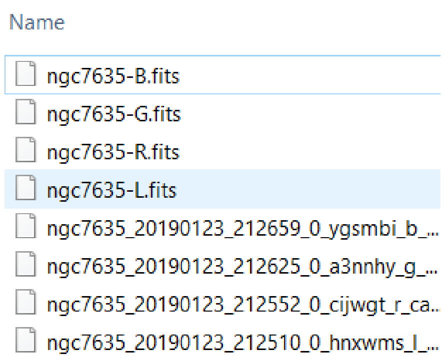
This setting analyzes the image and selects a range for the histogram at the bottom of the image. I show you how to modify this setting shortly, but for now, use the automatic setting.

Next, you need to align the images in your stack. I explained in detail how to do that in the preceding section "Aligning Your Stack", so follow the directions in the Aligning Your Stack in AstroImageJ to align your image, then return here to continue. You can select a galaxy or other large area to align your image or you can select individual stars - check your results to find out which works best for you.

Now that you have your images aligned, we're going to save each slice.

1. Create a new folder and call it "Aligned"
2. In AstroImageJ, drag the bar at the bottom of your image all the way to the right side
3. Note the name of the file near the top of the image window - what you want to note is whether this is an L, R, G, or B slice. You'll also want to give this file a name, so use the name of the object or think of some other memorable name
4. Select "File" - "Save image/slice as FITS…"
5. Enter the name of the object or memorable name and follow it with "-L" for Luminance, "-R" for Red, "-G" for Green, or "-B" for Blue
6. Append the extension ".FITS"
7. Click Save to save the file
8. Advance the bar at the bottom to the next slice in the stack
9. Repeat these steps from number 3 for the remaining members in the stack

My folder looks like this now:



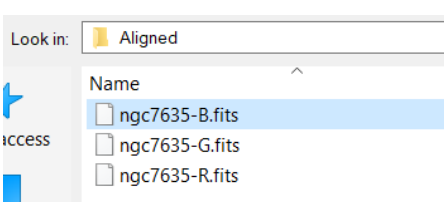
Close the stack of files in AstroImageJ.

Create a new folder called "Aligned" and move the R, G, and B files into it.

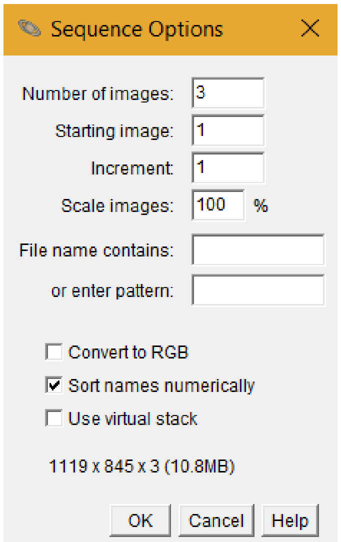
Create another folder called "Combine" and move the L file(s) into it.

Next, let's import the sequence of R, G and B files and tell AstroImageJ which file represents what color so that it can combine them properly. Once we've done that, we'll also bring in the Luminance file(s) for the best possible image.

Import the R, G, and B files as a sequence - select "File" - "Import" - "Image Sequence", find the "Aligned" folder and select the first image, as shown:

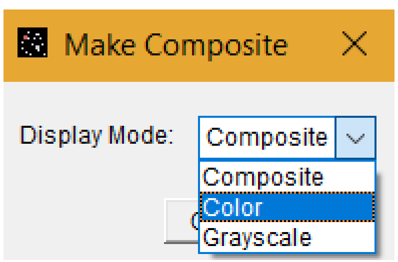


The "Sequence Options" window will pop-up:



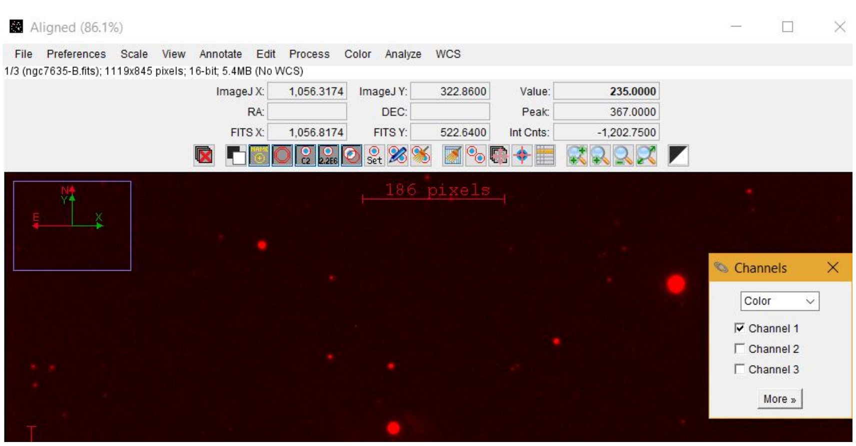
Verify that AstroImageJ found three files and clear the checkbox next to "Use virtual stack", then click Ok

Select "Color" - "Make composite image" and a new window pops-up:



Select "Color" for the "Display Mode" and click Ok.

Look carefully at your screen since a couple of things have changed. First, the image will be cast in a color, probably red, as shown in the screenshot below:



Next, a new window labeled “Channels” will have opened. It’s a small window so you might have to look around to find it - move it so that it’s easier to find since we’ll be working with it.

What AstroImageJ has done now is cast the image using the color filter was in place when the FITS image was taken. Chances are that it guessed wrong. You can verify which file you’re looking at by looking near the top of the image window for the name of the file. If you named the file using the names I suggested, you’ll be able to tell which filter was in place for this FITS file.

As an aside, another way to tell which filter was in place for the current slice of the stack is to review the FITS header. Click “Edit” - “FITS Header” or click the 15th icon from the left to view the FITS header window. Look for the entry labeled “FILTER” as shown:

16	YBINNING	3
17	XORGSUBF	0
18	YORGSUBF	0
19	FILTER	'Blue '
20	IMAGETYP	'Light Frame'
21	SITELAT	'28 17 59'

In this case the filter that was in place is Blue, yet the color cast on the screen is Red, so we need to correct AstroImageJ. Close the FITS header window if you opened it.

In the small “Channels” window, click “More” and then click “Blue”.

Drag the large bar at the bottom of your image to the next slice in the stack (the color cast will change). Check the name of the file, or use the FITS header to figure out which color filter was in place and correct AstroImageJ using the small “Channels” window to select the right color. Do this for each slice of the stack.

So now that you have the slices defined properly, you can compose an RGB image. In the “Channels” window, select “Composite” and then close that small window.

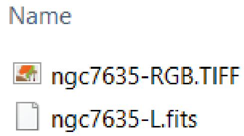
Now select “Color” - “Convert RGB stack to color image”. AstroImageJ will open a new window with the composite image.

This new image has a fidelity of 8-bits and you can confirm that by looking at the histogram at the bottom of you image and note that the values range between zero and 255. While this image looks good in terms of color, you’ve sacrificed fidelity (remember that the Slooh FITS images are 32-bit fidelity). This is fine if you don’t plan to use this image for photometry.

If you want to continue, this last step adds the luminance images to the RGB image. Recall that the luminance image represents the amount of light the camera collected when the telescope was pointing at your object.

Save this image by selecting “File” - “Save image/slice as TIFF”. Find the “Combine” folder and give your image a name; remember to use the extension “.TIFF”.

My folder looks like this:



Close the file you saved and now import the sequence. Select “File” - “Import” - “Image Sequence”. Find the “Combine” folder and select one of the images and click Ok on the window that comes up (after verifying the number of files in the sequence).

You should now have a stack of two images - one that’s your color TIFF image and one (or maybe more) that’s the luminance image. We’re going to combine the images in this stack.

From the smaller AstroImageJ window, select “Image” - “Stacks” - “Z Project”, and confirm the number of slices in the window that comes up. Select a “Projection type” - I usually select Sum to get the most of the luminance files, but that could over-expose your final image, so try the other options too. You can just go back and re-select the “Z Project” option from the window that has the stack already open to try again.

AstroImageJ displays the final image to you and there’s a chance it doesn’t look too good. This is what my screen looks like (it’s an image of the Bubble Nebula):

The image is grainy and washed out. This is happening because there’s a lot of nebulosity in the image that’s caused the “auto brightness & contrast” option under the Scale menu to adjust the image this way. In addition, you’ve lost some fidelity as I mentioned earlier. You can make adjustments at the bottom of the image by moving the black and white point markers along the histogram. Save the image as a TIFF file and continue editing in GIMP to get the most out of the image. I recommend you use the Curves adjustment in GIMP to try to get the most out of your image.

The nice thing about this process is that you have saved your changes as you went along, so starting from some point in the middle of the process is simple - you just open the files and resume editing.

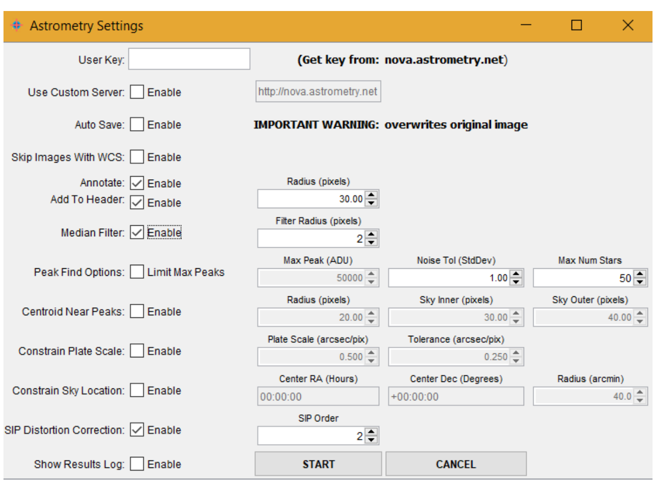
The next section discusses plate solving using AstroImageJ. Plate solving makes it easier to locate objects in your image and this is especially useful when doing things like multi aperture photometry, aligning, and researching the objects in your images.

Plate Solving Using AstroImageJ

As I mentioned earlier, AstroImageJ can plate solve images for you, making it easier to locate objects in your image. The plate solving process is integrated right into AstroImageJ and there are only a couple of settings to change to get it to work.

With an image open, select the 14th button on the toolbar - it says “plate solve using astrometry.net” when you hover your pointer over it:

A new window pops-up as shown:



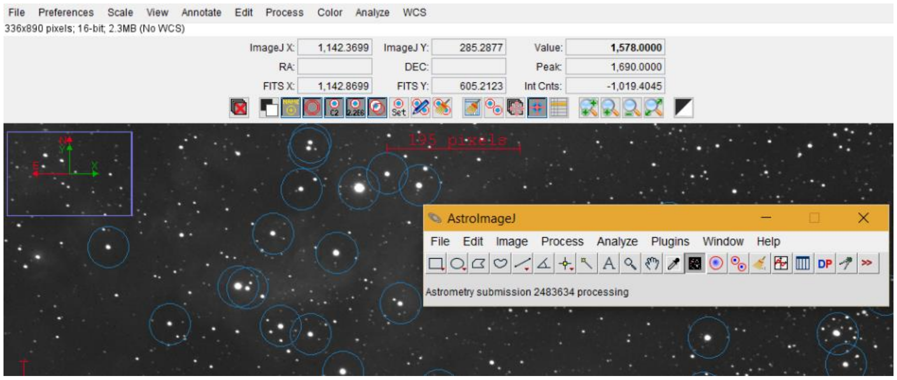
The important setting in this window is the “User Key” value.

You need to get this “user key” from http://nova.astrometry.net before AstroImageJ can plate solve for you. The process is simple, so I won’t walk you through it here. You basically sign in using something like your Google or Yahoo, or other provider’s ID. If you’re not comfortable sharing your Google ID, create another one for this process. I have had an ID with Astrometry.net for years and have never had an issue with it.

The “user key” is called an “API Key” on Astrometry.net, and Astsrometry.net makes it easy to retrieve your key. Select the API option or check your profile to find it.

Once you have the key, enter it on the preceding screen and click Ok to start the plate solving process. You have to enter your key just one time - AstroImageJ saves your key for future runs.

The screen will look something like this when the process is running:



The text under the toolbar in the AstroImageJ main window indicates that the plate solve process is running.

Since it is a free service, there’s a lot of demand for it, so it can take a number of minutes to plate solve your image. There’s a chance that AstroImageJ will tell you that your plate solve failed when in fact it is still either queued or running on the Astrometry.net site. If this happens, you can simply visit the nova.astrometry.net website and download your plate solved image from there once it is complete.

When you go to download your image from Astrometry.net, you’ll find that there are a number of FITS files available for you to download. You need to download the file called “new-image.fits” as this will contain the image and updated FITS header. The other FITS files don’t actually contain your image and contain table data instead. Note that you find your previous images under “Dashboard”, “My Profile”, “Images” - you may have to search through the images you see there to find your image.

With your plate solved image, the RA and DEC boxes will be filled in when you move your pointer across the image. The image’s FITS header will also be updated so now you can use it with multi-aperture photometry to detect exoplanets.

Exoplanet detection using AstroImageJ is well-documented, so I won’t describe it here. There’s a great resource in the “Online Resources” section that describes the process in detail along with a good set of sample files you can use. You do need a lot of data to use AstroImageJ effectively and five observations from Slooh won’t be enough to reliably detect a transit.

For the impatient, or if you are having difficulty with the nova.astrometry.net plate solver, you can download a plate solver server and index files to your local computer. This results in much faster plate solves because you’re the only person using it and it uses the same data that nova.astrometry.net uses, so there’s no loss in functionality. I run this server locally and have very good results with it. The next section briefly walks you through setting up the server and configuring AstroImageJ to use it to plate solve.

Downloading And Installing A Plate Solver Server

As I mentioned in the preceding section, you can use AstroImageJ to plate solve your images. AstroImageJ uses a public, free, and busy plate solver at nova.astrometry.net to provide this functionality to you. However, you can download and install a server locally that results in much faster plate solves because you're the only person using it and it uses the same data that nova.astrometry.net uses, so there's no loss in functionality.

Visit this site:

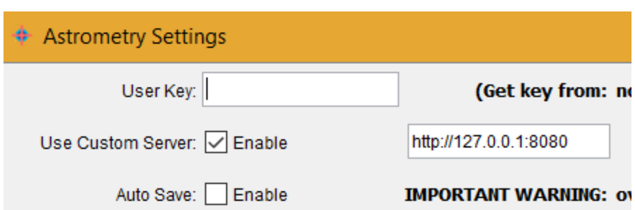
https://adgsoftware.com/ansvr/

The download and installation directions are listed there - simply follow the steps outlined at the website.

When it comes to the point during the setup process where you're downloading the indexes, the default is acceptable, unless you want smaller fields of view. I downloaded a couple of indexes and ended up with files totaling about 650Mb on my system, so the impact on disk space was not huge. You can download star catalogs that are much larger than that.

Once your download and installation finishes, back in AstroImageJ, edit the Astrometry Settings again. With an image open, select the 14th button on the toolbar - it says "plate solve using astrometry.net" when you hover your pointer over it:

You can clear out your "User key" since you won't need it anymore. Also click "Enable" next to "Use Custom Server", as shown:



If you didn't make any changes to Ansvr you can accept the default setting. AstroImageJ will now use your local plate solver and indexes to plate solve images. On my system, a plate solve takes about 10 seconds.

As a quick side note, when downloading the indexes, pay attention to the FOV or Field of View that the index you're downloading covers. You can get the FOV of the Slooh telescopes at the website, or you configured the FOV in KStars earlier. I noticed that when I am missing FOV indexes for an image I'm trying to plate solve that the plate solving process never succeeds. Try downloading some more indexes and that usually solves the problem.

The nice thing about this server is that other software can use it for its plate solving capabilities. Check with your software configuration to find out how to set it up.

Next Steps

Now that you have everything installed, working, and know how to use it, go forth and create beautiful and informative images!

Before I let you go, if you found this book useful, I ask that you post a review about this book in an astronomy forum, Facebook, Twitter, Instagram, or whatever sites you use.

The next sections is the "Software Installation and Configuration" section which you have already seen.

Beyond that is the "Online Resources" section where I provide links to resources I mentioned in this book.

I also discuss some personal issues like my software setup and workflows, my adventures in exoplanet hunting, my history with astronomy and how I came across Slooh, and I discuss the tools and workflows I used to create this book.

Software Installation and Configuration

This section covers the download, setup, and configuration of the software tools I use throughout this book.

All of the software is free to use so there are no costs involved. All you need is the ability to install software on your system and a reasonable internet connection.

Ensure you follow the configuration steps for the best possible experience with this book.

Let's get started.

DeepSkyStacker

DeepSkyStacker is a Windows image processing program designed for handling astronomic images.

We'll use DSS for processing some of our images.

Download DSS from here:

http://deepskystacker.free.fr/

The download link is on the left side of the page; click the download link. A new page will pop-up (this is at github,com); scroll to the bottom of the page and download DSS-Setup.exe. Run DSS-Setup.exe and follow the installation instructions.

You can access DSS from your Windows Start menu; just click the Windows Start menu and type the first few letters of DeepSkyStacker and the shortcut will come up for you to be able to click and start it.

7-Zip

7-Zip is a compressed file manager. We'll need this to unpack some files that we download during some of the exercises in this book.

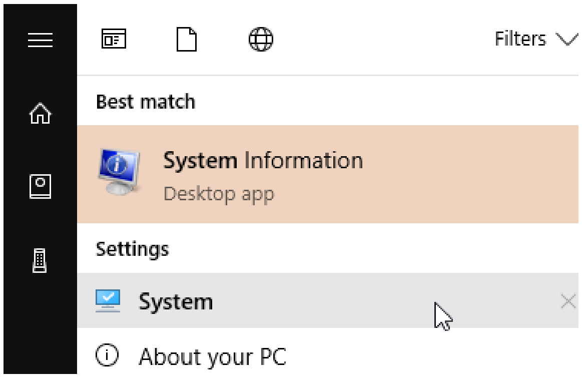
Download 7-Zip from here:

https://www.7-zip.org/download.html

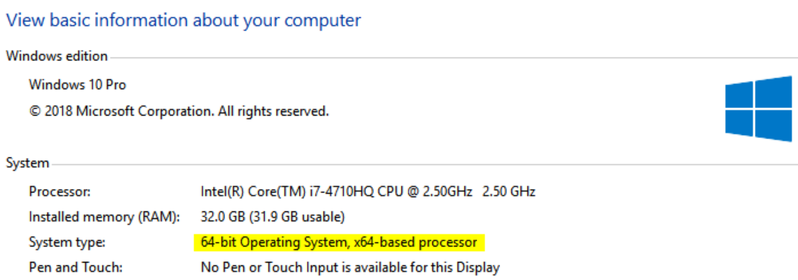
Select the link for your operating system - likely "7-Zip for 64-bit Windows x64 (Intel 64 or AMD64)".

The key choice is between 32-bit and 64-bit versions of the software. If you're not sure whether your system is 32-bit or 64-bit, you can easily find out.

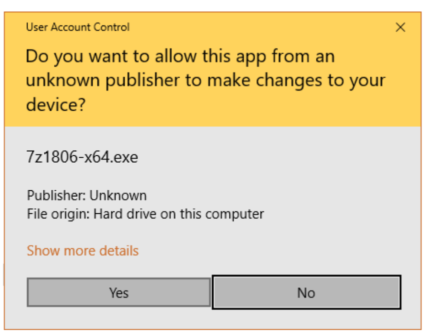
Click your Start menu and type System. Select the 'System' under the 'Settings' menu option:



A window appears showing you details about your system including whether it is 32-bit or 64-bit, as shown here:

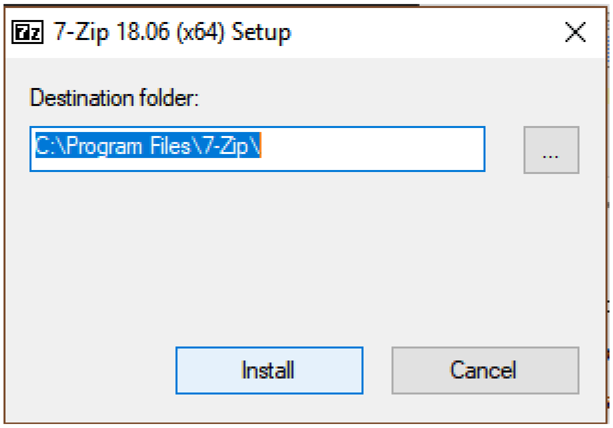


Once you have downloaded the file, double-click it to run Setup. When you double-click the file, a User Account Control box pops-up:



Click Yes to allow it to continue.

Another box pops-up. Unless you want to change the installation folder, just click Install to allow it to continue:



Once installation completes, click Close.

Configuring 7-Zip

Before we can use 7-Zip for the first time, just make sure that it will open the files we want to use correctly by following these steps:

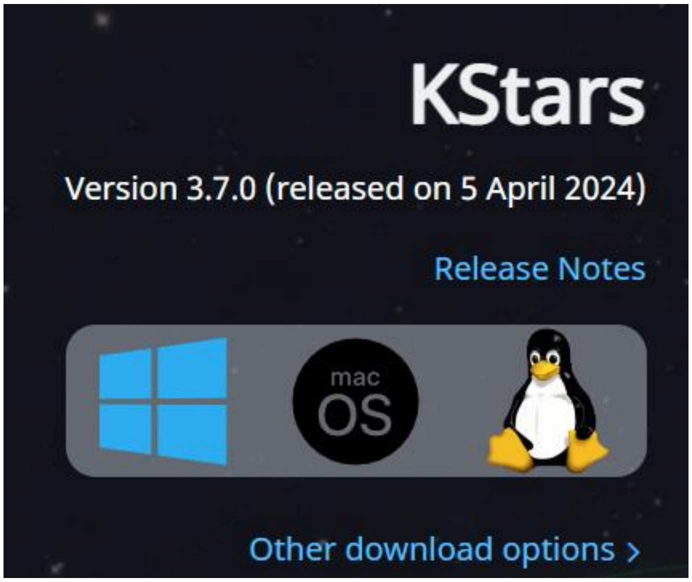
1. Start 7-Zip by clicking the Start menu, type 7-zip and click on 7-Zip
2. Click Tools - Options
3. Find “bz2” under the Type heading and highlight the row
4. Click the plus (+) symbol that’s at the top of the listing - choose the plus symbol on the left (there are two of them, choose the one on the left)
5. Click Ok
6. Close 7-Zip

KStars

KStars is a free planetarium software we’ll use for mission planning.

Download KStars from here:

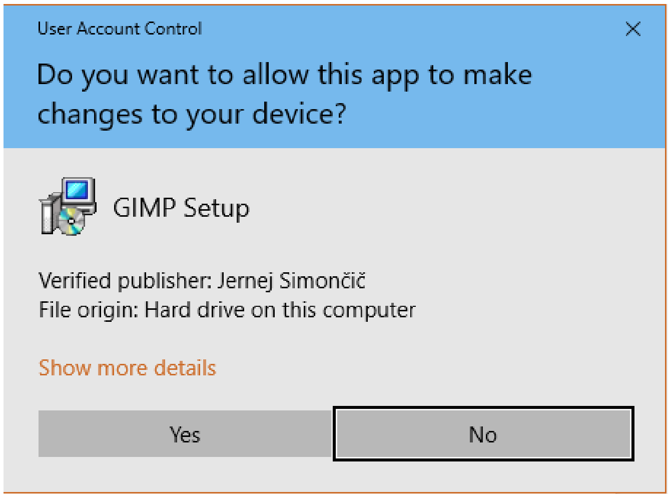
https://edu.kde.org/kstars/



Click the appropriate Download button to initiate the download.

Once the download has completed, double-click the file you downloaded (probably kstars-...exe).

A User Account Control box pops-up. Click Yes to allow it to continue:



Unless you want to change some settings, repeatedly click Next. And finally, click Install to allow installation to start.

The installation completes, proceed to the Configuration next.

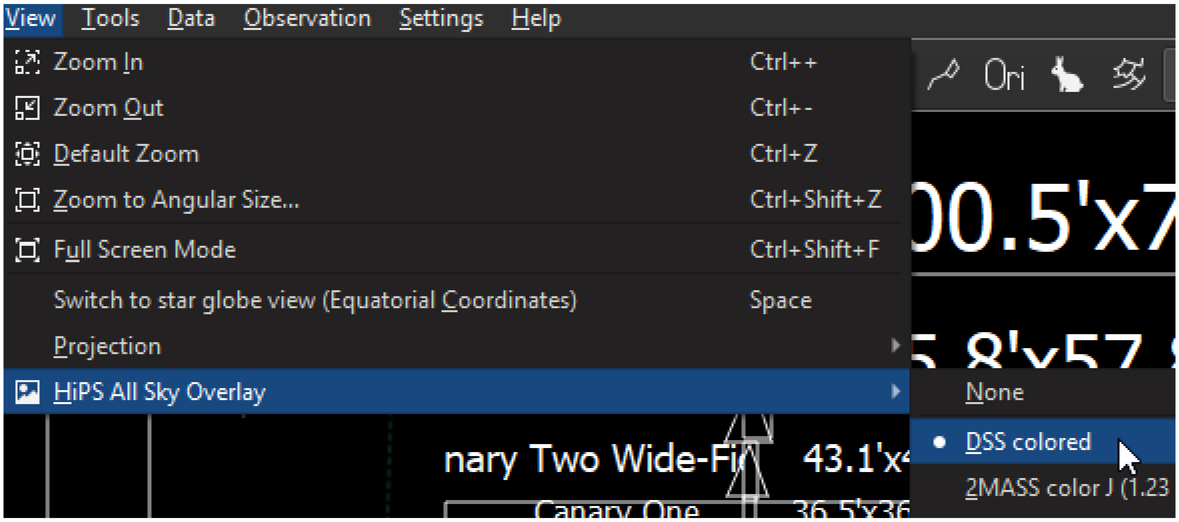
Configuring KStars

We'll have to configure some settings in KStars to make it easier to use with the Slooh telescopes.

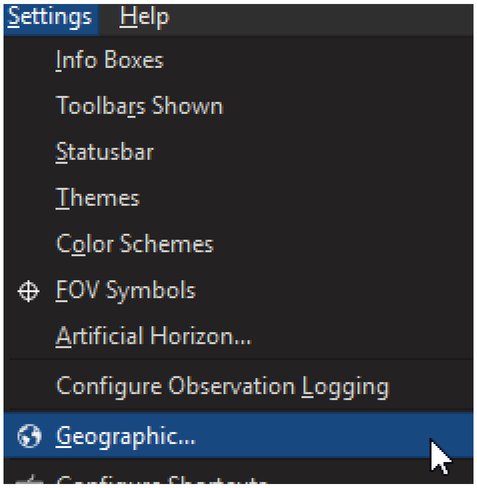
We'll first configure KStars to download images onto the planetarium sky map, then configure the location of the Canary Islands telescope, followed by setting up the field of view indicators.

Follow these directions:

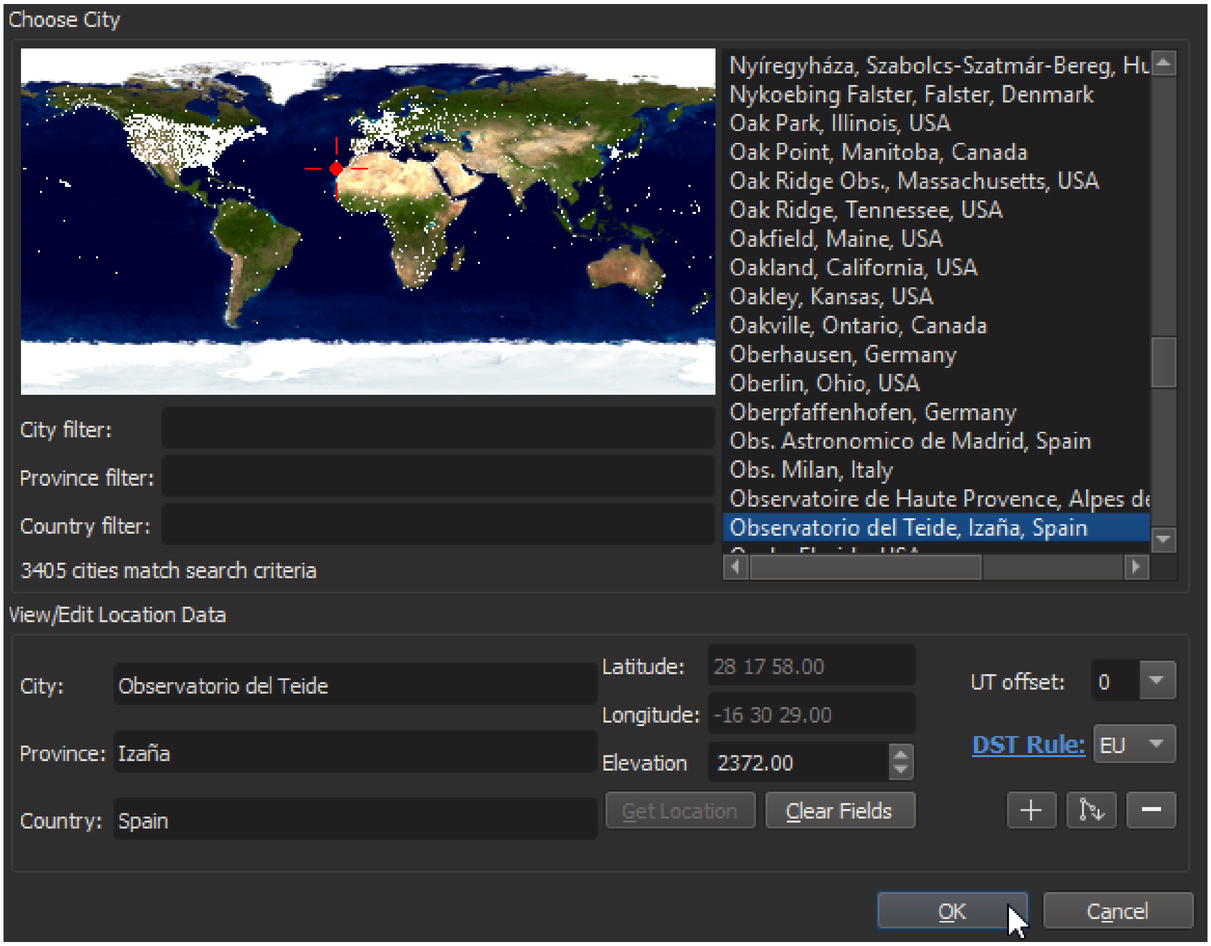
1. Start KStars by clicking the Start menu, type KStars, and select the KStars Desktop Planetarium shortcut
2. Click Close on the Tip of the Day box
3. Click View - HiPS All Syk Overlay - DSS Colored as shown:



4. Click Settings - Geographic as shown:



5. Enter the details as provided below:

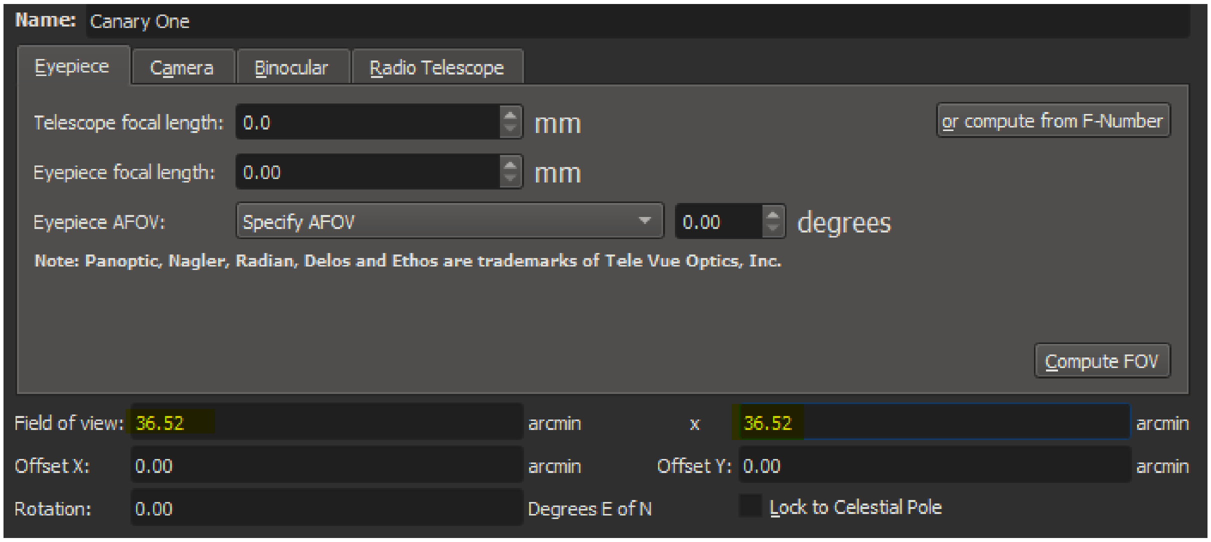


* Enter 'Observatorio del Teide' in the City field
* Enter 'Izaña' in the Province field
* Enter Spain in the Country field
* Enter the following in the Latitude field: 28:17:58.00
* Enter the following in the Longitude field: -16:30:29.00
* Enter the following in the Elevation field: 2372.00

6. Click Ok

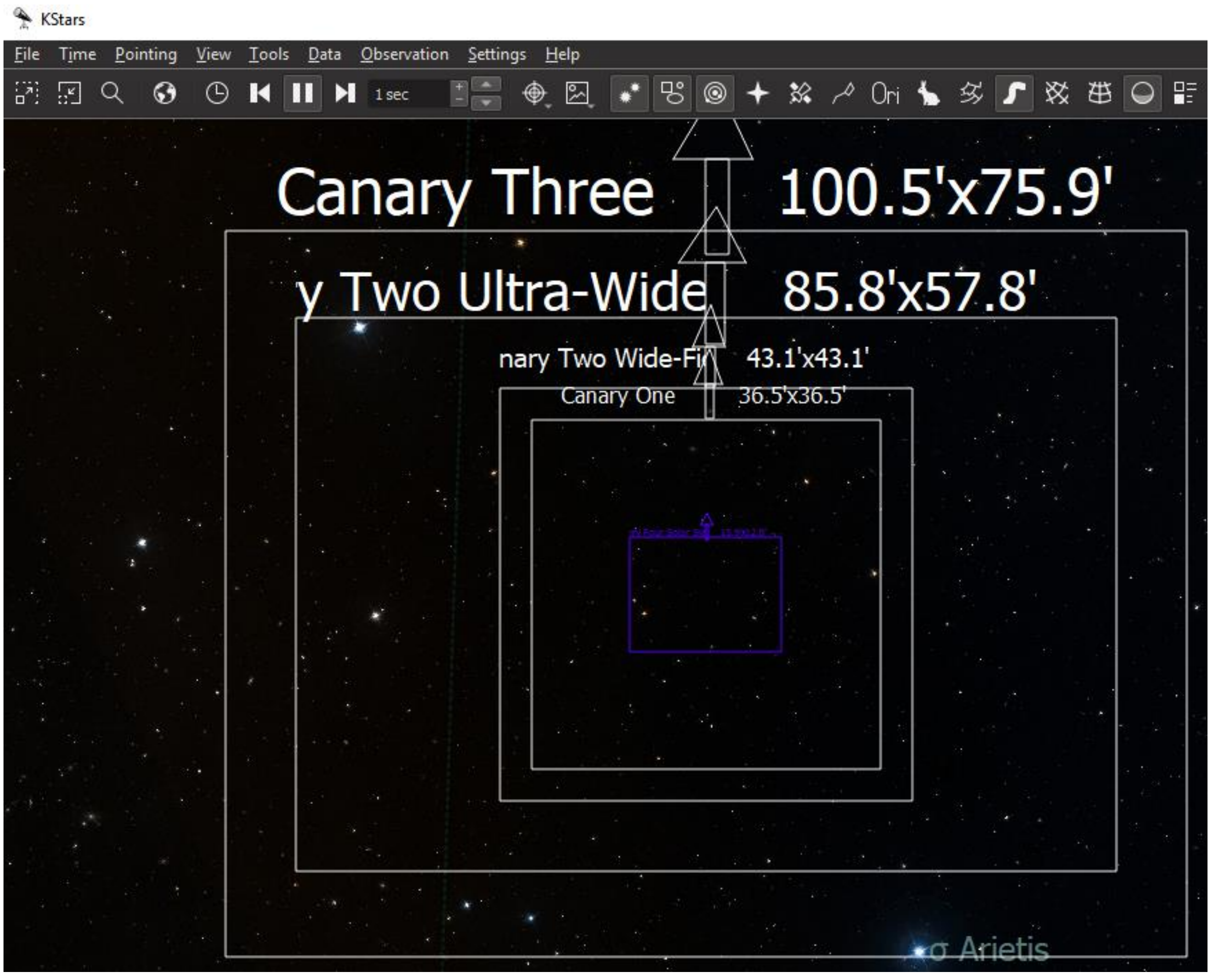
Now configure the field of view symbols/ We'll use these during mission planning. Use the following steps:

1. Click Settings - FOV Symbols - Edit FOV Symbols
2. Click New
3. Enter "Canary One" in the Name field
4. Enter 36.52 in both boxes of the Field of view setting as shown:



5. Click Ok
6. Click New
7. Enter Canary Two Wide-Field in the Name field
8. Enter 43.13 in both boxes of the Field of view fields
9. Click Ok
10. Click New
11. Enter Canary Two Ultra-Wide-Field in the Name field
12. Enter 85.81 and 57.83 in the Field of view fields
13. Click Ok
14. Click New
15. Enter Canary Three in the name field
16. Enter 100.51 and 75.90 in the Field of view fields
17. Click Ok
18. Click New
19. Enter Canary Four Solar System in the Name field
20. Enter 15.94 and 12.04in the Field of view fields
21. Click Ok
22. Click Ok to close the box
23. Click the FOV Symbols icon in the center of the top row of icons:

24. Click each of the name of each telescope you added so that it has a checkmark next to it. You should see something like this on your screen:



25. Close KStars

Next Steps

You can continue to install the next software in this section called AstroImageJ, but this is completely optional. Refer to the introduction in the AstroImageJ section, which appears next, for a brief overview and what we use it for in this book. If you decide that you just want to continue reading through the book, return to where you came from and pick up where you left off.

AstroImageJ

AstroImageJ is software that allows you to take scientific-grade measurements from your images and can help you in the detection of exoplanets. I include a chapter in this book on using AstroImageJ but since not everyone might be interested in taking measurements, downloading and installing this software is optional.

AstroImageJ just needs to be downloaded and copied to your system's hard drive - there's no installation process involved.

Start by downloading from this site:

https://www.astro.louisville.edu/software/astroimagej/

The page to download AstroImageJ is here:
https://www.astro.louisville.edu/software/astroimagej/installation_packages/

You'll need to know whether your system is 32-bit or 64-bit. I cover how to find out what your system is in the Software Installation and Configuration chapter, under the 7-Zip installation process. Just follow the few steps there to figure out what type of system you have before you download.

Once you have downloaded AstroImageJ, open the Zip file and extract the contents to a folder on your system.

I find that AstroImageJ prefers to run from the C: drive of your system, so if you install it onto another drive like D: or E:, you'll find it has issues running, producing all sorts of strange error messages. Some people report that they get fewer errors running AstroImageJ from a folder other than "Program Files" - you can just move the folder to some other location to try it out.

Once you have AstroImageJ installed, double-click AstroImageJ.exe or use the shortcut you created to start it.

Note that AstroImageJ is written in Java, so you'll have to have it installed on your computer to use it. Chances are that Java will already be installed and ready to use. If not, you can install Java on your system yourself. Do a Google search for "install java" and you'll be directed to site at java.com to go through the installation process.

Next Steps

Congratulations, you have completed this section. Depending on where you came from, you might want to go back and continue following along.

Appendix

My Software Setup And Workflows

I'm always curious about how others work and what tools they use, so I thought I would give you some insight into how I work.

When I first came to Slooh, I had no idea what I was doing – I was completely lost and became dejected early on. In fact, I left Slooh for a while because I really didn't know what to observe or how to go about doing it despite all the great online help and community.

While I was away from Slooh, I did lots of reading and decided that I would jump right in and not hold back this time. So, I researched the tools available on the market and eventually came across what I think are among the best tools available for producing final images:

- TheSkyX Professional Edition
- MaxIM DL
- PixInsight
- PhotoShop
- AstroImageJ
- Astrometrica

You'll notice that the first three tools are paid software. So why did I decide to pay for tools and write a book using only free tools? It came down to the amount of time and effort I wanted to put into working with my images.

I have only a couple of hours where I'm free each day. I have some more time on the weekend but that's limited too. So, I wanted to make the best use of the time I did have. I wanted to be able to produce reasonable quality images in a reasonable amount of time.

Having researched the issues with the free tools, I decided I would go for the best that I could afford and haven't looked back since.

An example of what MaxIM DL offers that simply isn't as good in the free tools I have tried: stacking. I take many photos of the same subject using different telescopes, so you have different fields of view, and often use the multi luminance processing recipe to get as much light as possible. In MaxIM DL, I can stack literally over 100 files with just a few clicks. The software is able to align images so precisely – I don't have to pick a reference star or really do much. I just setup the process and within minutes I have a stacked and aligned image ready for processing.

Moreover, I mentioned that there are different ways to combine a stack – the most common of which is Add, where the pixel values of members of the stack are added together. There are, however, several different options and MaxIM DL makes it possible to explore those options with very little effort. I would much rather be processing my images rather than aligning them for each stacking operation.

How I use TheSkyX Professional Edition

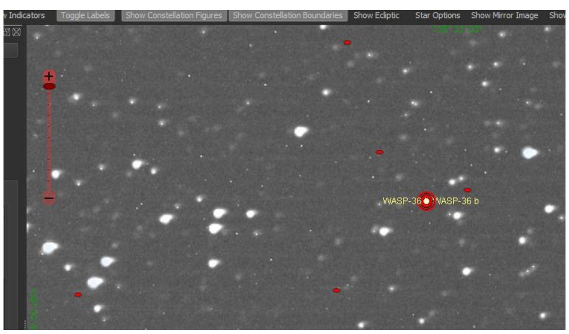
The edition I use is actually meant for advanced telescope control, but it has features elsewhere in the application that make it worthwhile.

I like to measure the transit of exoplanets. I use Slooh as well as other services to capture the images I use to measure the transits. In cases where I don't take the photos, I'm often left with many images of a field of stars, not knowing at all where the star with the transiting planet is in the image. This makes measurement almost impossible.

While I could certainly use a service like Astrometry.net to plate solve, it doesn't have exoplanets in its database (at least the last time I checked), so I would have to use the plate solved image to hunt down the star and exoplanet.

TheSkyX makes the whole process much easier. I simply use a feature called Image Link – which is their version of plate solving, and within 10 seconds I not only have a plate solved image, the image is projected onto the planetarium screen and I can have TheSkyX highlight exactly where the star and exoplanet are!

Here's a screenshot showing the exact location of WASP-36b:



It took about 10 seconds to plate solve this image – saving me a great deal of time.

TheSkyX can be kept up to date with data from the Minor Planet Center to track down asteroids – something that's become of interest lately. I can use TheSkyX to pick candidate asteroids from a very large database that's always up to date. I can filter by altitude, magnitude, and many other factors, making planning really easy. It's also easy to compose my images so that I get the best result I'm able to get. In addition, the plate solving capability in TheSkyX makes it possible to quickly find an asteroid in a field of stars making identification simple too.

How I use MaxIM DL

MaxIM DL's primary purpose is really in capturing images but it's also great for post processing. I recently captured an image of NGC 7380 – the Wizard Nebula - and this is the image I got from Slooh:

I was a little disappointed because there wasn't anything of the nebula in the photo from Slooh. I used the 'Faint Nebula' processing recipe but the stretch Slooh applied just wasn't working for the image.

I downloaded the FITS files and got to work and in about 20 minutes, I ended up with this image:

This is a great result – the background is dark, you can see the details in the nebula, the stars are well-resolved. The only drawback I see in the image is that some of the stars are purple, which should not be the case. But I think I accomplished a lot in 20 minutes.

In addition, as I mentioned earlier in the introduction to this section, stacking is so easy. MaxIM DL is able to figure out what filters were used, is able to align images from different fields of view, I can configure quality settings to reject FITS files that don't meet the criteria (like stretched stars, or maybe the wind affected the mission).

How I Use PixInsight

PixInsight is advanced image processing software; it's unlike other software available on the market and provides a lot of advanced functionality including background modelization, advanced transforms, noise management, scripting, and much more.

I produce most of my images using PixInsight.

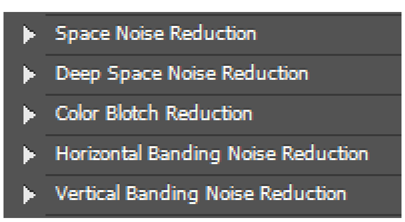
How I Use Photoshop

Although I use GIMP in this book, I actually learned about image processing using Photoshop. While you can certainly process images using GIMP, I find that Photoshop offers tools and capabilities that aren't available in GIMP.

As I mentioned earlier, I have limited time and I found that a lot of my image processing was repetitive. Common repetitive tasks include reducing noise, removing horizontal bands, enhancing deep space objects while leaving the rest of the image alone, and the list goes on.

I found that someone has already solved the repetitive nature of processing problem by making a series of 'actions' available. These 'actions' are essentially pre-recorded steps that Photoshop carries out to accomplish a particular task.

Here's a screenshot of just five of the more useful actions:



You just click the action you want Photoshop to carry out and click Play – it does the rest. And these actions are not simple by any means – clearly a lot of work has gone into them.

In addition, Photoshop supports non-destructive editing and has amazing support for layers. The non-destructive editing capability is alone worth the price of Photoshop – it makes editing images really fluid and promotes experimentation.

How I use AstroImageJ

I incorporate AstroImageJ into my workflow when I want to do things like plate solve my images to make hunting for asteroids or exoplanets easier. I also use it for creating animated GIFS of moving targets, perform photometry and sometimes use it to produce my final images.

How I use Astrometrica

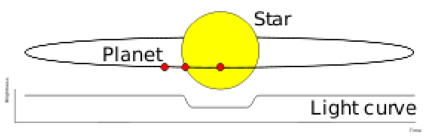
Astrometrica is a data reduction tool used to find things like asteroids, comets and other known objects in an image. I recently became interested in astrometry – studying the position of objects in the sky and Astrometrica makes it easier to find things in my images. It's pretty specialized software so it's not at all suitable for producing nice images of galaxies but if you're interested in moving objects, this is definitely the way to go.

There are a lot of Slooh members that use Astrometrica and there's a group called "The A-Team" that provides training on how to use Astrometrica to locate, process, and report moving objects.

My Adventures In Exoplanet Hunting

One of the things that has intrigued me for a long time is exoplanets. I remember the first confirmed exoplanet, Dimidium or 51 Peg b, and was amazed that we actually discovered a planetary system similar to our own. Of course, the exoplanet was not earth-like but that was not the goal – the goal was to confirm the existence of an exoplanet which this definitely was.

I learned all I could about the research and gained an understanding of how exoplanets are detected using the transit photometry method. Here's a diagram that gives you a quick overview of the method:



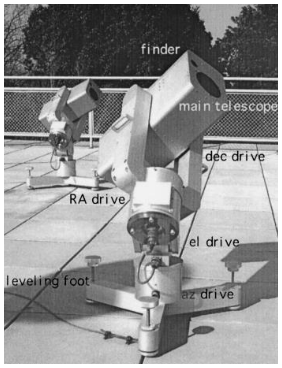
The light curve of the star reduces each time a planet passes in front of it. The reduction in intensity isn't much, but it's enough to confirm that something's going on. While I liked looking at the graphs of exoplanets using data collected by professional astronomers, I wanted to find out if I could collect enough data to create a similar graph.

Armed with access to the Exoplanet Transit Database, or ETD, (http://var2.astro.cz/ETD/predictions.php), I decided to try capturing images to use for photometry using Slooh.

I researched which exoplanets were going to transit using the ETD and booked missions. My results were not that great mainly because I was limited to five missions. To observe a transit you need observations before, during, and after the transit. Although I timed my missions in that way, five readings simply weren't enough to be able to get the type of graph I was looking for.

As I mention in the section, "My History with Astronomy and How I Found Slooh", I discovered Slooh after I came across the MicroObservatory.

The MicroObservatory is a small network of remote-controlled telescopes each having a six-inch aperture. The telescopes are not housed in a dome like the Slooh telescopes are housed – these are located outside. Here's an image of one of the telescopes:



You schedule a telescope by selecting objects from a listing of available objects and your mission gets scheduled on a telescope.

Here's a screenshot of the object selection screen:

Usually the next day, you get an email with a link to your image and FITS file. Sometimes it takes more than a day if the telescopes were closed due to weather.

So, what does this have to do with exoplanet transits? It turns out that you can schedule the MicroObservatory telescopes to observe an exoplanet transit and you get hours of observations! I provide a link in the Online Resources section where you can schedule an exoplanet transit observation.

Similar to Slooh, the MicroObservatory is all about sharing so they make an archive of their observations for the past month available to anyone. Looking through the archive, I was able to view past missions that included exoplanet transits. Here's a screenshot from the archive:

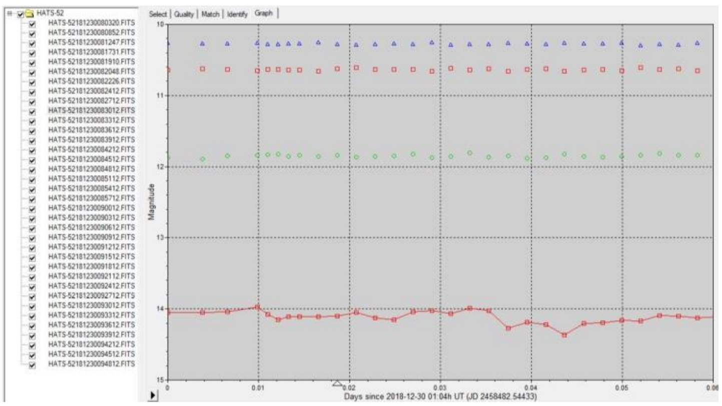
Dark-C-190117084900	17-Jan-19 08:49	JS9/4L	Main	60.00	Opaque	Dark-C-
HATP-10190117084512	17-Jan-19 08:45	JS9/4L	Main	60.00	Clear	HATP-10
HATP-10190117084212	17-Jan-19 08:42	JS9/4L	Main	60.00	Clear	HATP-10
HATP-10190117083912	17-Jan-19 08:39	JS9/4L	Main	60.00	Clear	HATP-10
HATP-10190117083612	17-Jan-19 08:36	JS9/4L	Main	60.00	Clear	HATP-10

The exoplanet in this case is HATP-10.

I was able to acquire lots of images, but the next thing was to figure out how to create a light curve graph using the data.

Fortunately, the FITS files available from the MicroObservatory are filled in with the right ascension and declination along with other details about the observation, making it easier to align the images using something like MaxIM DL or AstroImageJ.

While I won't get into the details of how I worked with the FITS files, I did manage to create light curves using MaxIM DL, as shown:



This image is a graph of the light coming from the reference and host star of the exoplanet HATS-52. The line at the bottom of the graph is the light curve from the host star. The other three lines in the upper part of the graph are the light curves of reference stars having known magnitudes to compare against. You use these reference stars to ensure factors like seeing and other conditions do not contribute to the light curve from the star you're measuring.

From the graph you can clearly see a dip in the light intensity coming from the host star whereas the light curves from the reference stars remain unchanged, indicating that this is indeed a transit happening!

I have been creating graphs like this from my own MicroObservatory reservations and using others' data for many months now and always get a kick out of it when I see a confirmed transit.

My History with Astronomy and How I Found Slooh

I have always been interested in photography, taking as many pictures as I could to see what results I could come up with. In my late teens, I bought a used 35mm camera and took it out into the winter night to see what kind of image I could capture from the night sky. My first attempts were not that good, but I learned quickly. Looking back at it, those first images were mostly of a dark sky because where I was shooting was a very light-polluted area and few stars were resolved.

I bought a sky atlas at the time but couldn't make sense of all of the lines and figures on the map. I did learn about altitude and azimuth and managed to view a few stars using that to locate them - it was a small victory.

I was an avid reader and subscribed to all sorts of magazines including Discover and National Geographic. I also read Stephen Hawking's "A Brief History of Time" and was completely captivated by the physics behind what was in the sky. I have read that book many times and still re-read it today even though the information is slightly out of date.

Later, I joined the astronomy club in high school. We mostly sat around and discussed the sky and I found it very uninspiring and almost quit the club. Then, one meeting, the teacher who was also the head of the club announced that we were going on a field trip to the David Dunlap Observatory one night. I was intrigued by its description and also by the fact that black holes were proven to exist at that observatory.

We went to the observatory one night and from the moment I saw the large telescope, I knew I was hooked. It was not a good night for observing but they did have the large telescope pointed at a globular cluster. It is the only globular cluster I have ever seen through a telescope, but it was the most beautiful thing I have ever seen. Outside, on the grounds, some people had set up their own telescopes and I was intrigued by how open they were with sharing their knowledge. I looked through one of the telescopes and saw Saturn. I was amazed that you could see those two things through the telescopes.

That night, I was unable to sleep - I was too wound up by all of the thoughts of planets, stars, and other things I had seen. Suddenly, events like the Voyager takeoff, and photos it had taken and I had seen as a child made much more sense - they went from being fragments of curiosity to things that I was beginning to understand.

While my life changed quite a bit, my interest in astronomy always remained the same. I took every opportunity I got to look up at the night sky, I read a lot, and thought a lot. I stopped pursuing astronomy as a hobby because I had neither the time or money to put into it. I also felt that I didn't have a good understanding of what I needed to actively pursue the hobby anyway.

Much later on, I was searching online for things to view in the sky. I was a journalist at an online publication and was writing a story about space. I needed a photo of something spectacular to include with the article and was searching through images. I saw a lot of images, mostly from the Hubble Space Telescope, and was intrigued about all of the nebulas, galaxies, globular clusters, and other objects I found. I decided it was time to get back into astronomy, but knew now that where I live is not an ideal site for observing, so I needed something different.

I came across a site called the MicroObservatory (http://mo-www.harvard.edu/OWN/) where you can participate in remote imaging for free. You pick an object from a list of things to view, their telescopes image it, and send you a photo in one or two days. This is where I got interested in the idea of remote imaging and I still use the MicroObservatory today.

After much searching, I came across Slooh in 2014. It didn't take me long to sign up and start taking photos. You'd think I'd be thrilled at finally being able to just pick something and have an image of it the next day, but I was underwhelmed. The photos I got were, understandably, not like those that I had seen online. I also had no idea what to take photos of since I was still gaining a better understanding of the night sky. So I stopped taking photos and went back to what I was good at - reading. I learned a lot and returned to Slooh a few months later, this time armed with knowledge of how the telescopes work, what image processing is all about, how to find objects in the sky, and a range of other issues.

Ultimately, I managed to find my way. I now take great photos and do my own research using Slooh. I decided to produce this book to share what I had learned.

Tools and Workflows I Used To Write This Book

If you read any forums or go to any astrophotography image sharing site, the first thing people ask after seeing an image is how the photographer got the image: they want to understand about the telescope, camera, and software used to create the image. People want to know that information so that they can better understand the process of creation and perhaps replicate the results.

A book about astrophotography would be incomplete if I didn't explain the tools and workflows I used to create the book.

I wrote this book in various locations using various computers. I primarily used Google Docs to write the chapters and keep them safe as I wrote. This allowed me to move from computer to computer while having all of my working files stored and safely backed-up.

I started the book by creating the table of contents – this took quite a long time and was probably the most boring part of the whole process. I had written other books in the past and knew that being grounded using the table of contents would make a big difference even I was eager to start writing. I designed the table of contents to be cohesive and easy to follow.

With the table of contents complete, I broke up my workflow between writing and developing examples. I could only take screenshots and install software on one of my computers, so I worked though examples and took screenshots all at one time. I took notes about what I wanted to say about each screenshot and kept everything together in a single Google Document.

Once I had all of my screenshots, I created the sample images I needed by booking missions, processing images, and saving them as I went along.

I then started writing the chapters by following my table of contents. I adjusted the table of contents as I made progress to add or remove content as I felt the need to.

Once writing was complete, I merged all of the content into one big Microsoft Word document. I added heading styles, fixed formatting, adjusted the sizes of screenshots and images, adjusted the page layouts and a lot of other boring things.

I kept the book backed-up using both Google Drive and Dropbox in addition to having a couple of copies on my computer and an external hard drive.

I created the final PDF version of this book using Microsoft Word.

The software I used to create this book includes Paint.net, Photoshop, Greenshot, Microsoft Word, AstroImageJ, KStars, TheSkyX, MaxIM DL, PixInsight and of course the Chrome browser.

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