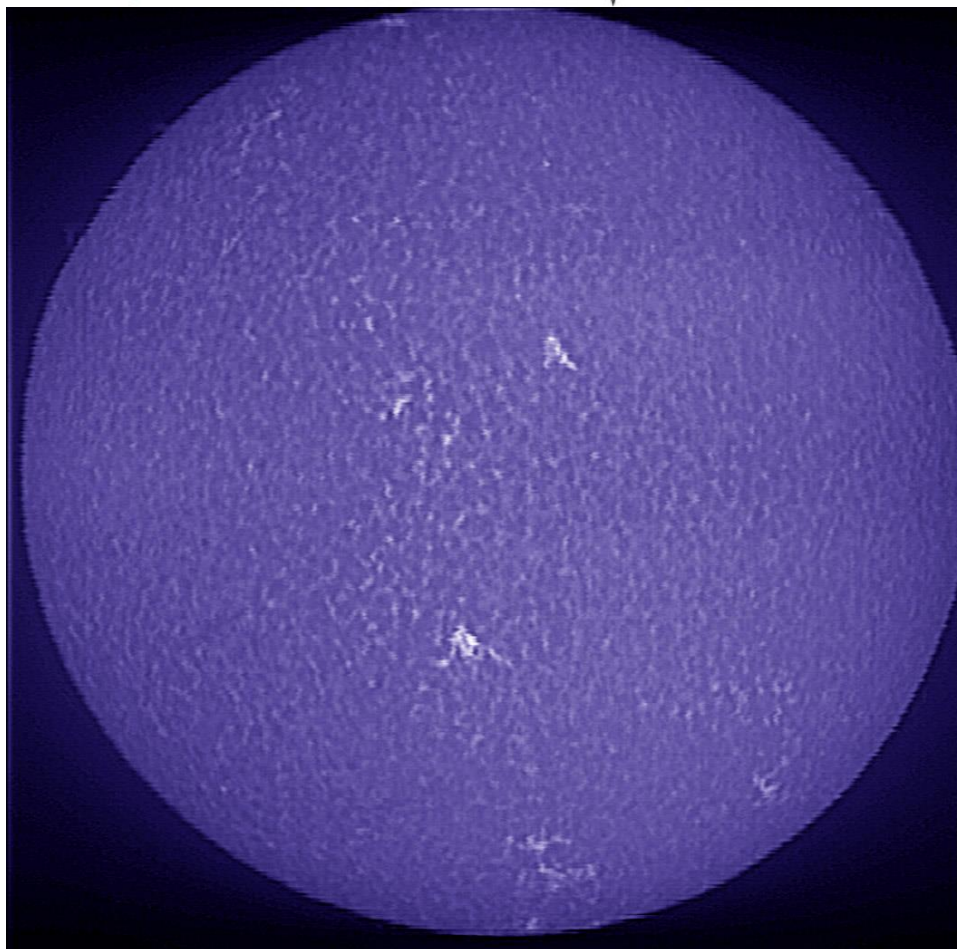


SkyWAAatch



How to Shoot the Sun

A Spectroheliograph is an instrument which employs a diffraction grating or prism to photograph the Sun at specific wavelengths. Developed independently in the 1890s by George Ellery Hale and Henri-Alexandre Deslandres, the Spectroheliograph allows the photographing of fine detail on the Sun despite the overwhelming amount of solar glare.

Above is a Spectroheliogram taken in the CaH line (396.85 nm) by the John Paladini using his homemade Spectroheliograph. On page 4 of this issue of the *SkyWAAatch* John provides "A Quick Guide to Building a Digital Spectroheliograph."

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- pg. 13 Light Curve of RZ Cassiopeia (RZ Cas)

Events for April

WAA April Lecture

"The Wobbly Universe"

Friday April 7th, 7:30pm

Leinhard Lecture Hall,
Pace University, Pleasantville, NY

Our speaker, Professor Hans Minnich, will address the question of why your star finder is not completely accurate and never will be. The equations used by sky programs to calculate the position of celestial objects do not take into account all physical influences acting on the earth, moon, planets and stars. Therefore there is an inherent inaccuracy in the predicted position and movement of the sky. Even if all influences could be accounted for it would still be presently impossible to find exact solution to these equations.

Professor Minnich will discuss some of these influences, which are generally ignored, and why the predictions will become increasing inaccurate the farther in the future you go. Mr. Minnich has been part of the Fordham University faculty as a Lecturer and Astronomer since 1980. He manages the observational astronomy facilities and labs for the Department. He has an MS in Physics from Hunter College, CUNY. [Directions](#) and [Map](#).

Upcoming Lectures

Pace University, Pleasantville, NY

On May 5th, our presenter will be Andy Poniro.

Starway to Heaven

Saturday April 22nd, Dusk.

Ward Pound Ridge Reservation,
Cross River, NY

This is our scheduled Starway to Heaven observing date for April, weather permitting. Free and open to the public. The rain/cloud date is April 29th. **Important Note:** By attending our star parties you are subject to our rules and expectations as described [here](#). [Directions](#) and [Map](#).

New Members. . .

Louise Mullan - Hastings-on-Hudson
Rena Hecht - Rye

Renewing Members. . .

Frank Jones - New Rochelle
Theresa C. Kratschmer - Yorktown Heights
Lawrence C Bassett - Thornwood
John Benfatti - Bronx

Neil Roth - Somers

David Parmet - Pound Ridge

Pierre-Yves Sonke - Tarrytown

Emily Dean - Pelham

Jim Cobb - Tarrytown

Oliver E. Wayne and Elizabeth Scott - Cliffside Park

Karen Seiter - Larchmont

Richard Grosbard - New York

Join WAA at NEAF, April 8-9th Rockland Community College, Suffern, NY

WAA will have a booth at the [Northeast Astronomy Forum](#), to be held at Rockland Community College on Saturday, April 8th and Sunday, April 9th. This is the nation's premier astronomy show, with a vast diversity of exhibitors, vendors, equipment, lectures by leading astronomy figures and, weather permitting, the famous Solar Star Party.

We need volunteers to staff our booth. It's an opportunity to meet and chat with fellow club members and other astronomy enthusiasts, and to help recruit new members to the club. It also is a place where you can store your swag while attending lectures or other events. Last year 20 club members participated, we recruited new members and we made many new friends. Put NEAF in your calendar now.

Wanted Assistant Editor

The WAA newsletter (the *SkyWaatch*) is seeking an Assistant Editor. If you can help, please let us know. Your participation in editing, compositing and proofreading tasks or submitting articles or images, will be much appreciated. Email Tom at waa-newsletter@westchesterastronomers.org.

Call: 1-877-456-5778 (toll free) for announcements, weather cancellations, or questions. Also, don't forget to visit the [WAA website](#).

ALMANAC

For April 2017 by Bob Kelly

April has Leo the celestial lion leaping high in the southern sky, chasing a . . . crab? Anyway, let Leo point the way to the bees of M44 – it's good with any optical aid you have. The magic of moving to daylight time made Orion seem to hang in the evening sky like a trapeze artist caught in mid-flight. But, this month our high flyer seems to be rushing for the exit, taking the circus with him. There go the Bull, the Charioteer and the conjoined twins, even the dog acts are heading west. The Milky Way seems to sweep them all off stage as the Dipper rides high, spilling its cargo over a shocked Polaris and a drowned King standing below.

Mars stands by the western exit, seeming to hold its position as the Celestial Menagerie surges toward the sunset. The reddish planet may not be as bright (luminously speaking) as the fleeing customers, but instead stands like a conductor, counting those who rode the train that day. We can watch this and do our own count as the Hyades and Pleiades appear to sail past Mars around the 20th. Binoculars may be needed. While Mars is still setting at the same time each night as it has for many months, the Sun is setting later and its glare is encroaching on Mars' position.

The Moon serenely glides through these scenes, paying no heed to the passing crowd. Planetary paparazzi should try to catch the crescent moon not quite in line with Mars and the pretty clusters on the 28th after trying to drown out mighty Jupiter on the 10th.

Luna looks a football about to be kicked by the foreleg of Leo on the 6th and passes a ways from Saturn on the 16th and 17th. Lunar perigee is 28 hours after new moon – making it a 'supermoon' - if we could see it. But, the Moon gets to kick up the tides with higher than normal tides for several days after new moon on the 26th. The Moon reprises its run through the Hyades cluster on the 28th, but it's a daytime show near 2pm; with the thin Moon not very far from the Sun.

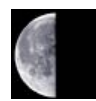
Look for Saturn low, but not too low, in the southern sky in the morning. I've found Saturn needs at least 30 power magnification to see the rings. See how many of Saturn's moons you can spot! The large tip of Saturn's rings toward Earth increases the dramatic view, but tends to drown out the fainter moons. Look also for Saturn's typically low contrast atmospheric



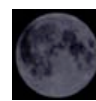
Apr 6



Apr 11



Apr 19



Apr 26

bands, like finding butterscotch in french vanilla pudding.

Still looking for something else that's good with *any* optical aid? Jupiter is the star of the show this month, with Earth making its closest pass on the 7th. Only Venus is looking larger in our skies (if you don't count the Sun and Moon and occasional comet!). Is Jupiter's Great, Red, Spot doing at least two of the three?

Look early in the month and early in the evening, low in the west as Mercury starts out the month setting at the end of twilight. The innermost planet dims as it zips around the Sun into the solar glare.

Venus is barely out from its trip in front of the Sun, rising into the morning skies. If you missed the crescent phase in March, or even if you didn't, watch from time to time as the crescent grows wider and the disk shrinks as Venus leaves Earth behind for about the billionth time.

The weak Lyrid meteor shower peaks on the morning following our Saturday, April 22nd star party. At 20 meteors an hour, tops, about a handful may be visible. The crescent moon tries to horn in on the scene, but won't be a bother this time as the radiant rises high in the sky by morning twilight.

The occasional comet has passed our way lately. The latest in the hard-to-remember names is Tuttle-Giacobini-Kresak (41P), leaving Ursa Major and moving through the fainter stars of Draco. It may brighten to +6th magnitude this month.

The International Space Station will grace the evening sky through the 16th.

The Cassini spacecraft makes another pass by Titan to bend its orbit to *between* Saturn and its rings. More and more ring structure is visible during each of the latest close passes outside the rings. I'm excited to see what the rings look like from the inside.

A Quick Guide to Building a Digital Spectroheliograph

John Paladini



The spectroheliograph optics

Today we take for granted reasonably priced commercial solar telescopes that show the sun in its glory at specific wavelengths of light, mostly hydrogen-alpha (in the red end of the spectrum at 656.28 nm) or calcium-K (in the ultraviolet at 393.37 nm). Different features of solar structure are visualized at each wavelength. However, seeing the sun at very narrow bandwidths was not possible before about 120 years ago.

To view at these specific wavelengths, astronomers use special filters designed to pass just that wavelength. But wouldn't it be interesting to be able to study the sun at *any* wavelength in the visible spectrum? The device needed to do this is called a spectroheliograph.

Before I describe how I built my digital spectroheliograph there must be a few definitions and disclaimers.

This article is a summary of what you need to build a compact version of a classical digital spectroheliograph. Many details about the theory of spectroscopy and spectroheliographs are left out. That infor-

mation has been well documented and would require several hundred pages. At the end of this article you will find a list books and websites that will help you to fill in the gaps.

Since you will be observing the sun, [standard precautions](#) and care about solar observing must be followed. You must accept full responsibility when embarking on any solar project, and you need to follow common sense safety rules.

Definitions

A *spectroheliograph* (SHG) is an instrument that records an image of the solar disk at a specific wavelength. The image is called a spectroheliogram. The advantage a SHG has over a filter-based system is that any one of the continuum of wavelengths are available to view, while a filter-based scope can only show one specific wavelength. The sister to spectroheliograph is the *spectrohelioscope* (SHS), which allows a live direct view of the image.

A *spectroscope* is the part of the spectrohelioscope that separates white light into its component colors (wavelengths).

A *dispersion grating* is part of the spectroscope that does the actual job of separating the light into its component wavelengths. Glass prisms can be used to disperse light, but they are not as useful for this kind of instrument and are not discussed in this paper.



Isaac Newton, Joseph Fraunhofer, Pierre (Jules) Janssen

A capsule history of spectroscopy

Although people had been seeing rainbows and spectra in beveled glass windows for many centuries, the formal discovery that "white" sunlight is composed of a range of colors is credited to Sir Isaac Newton, who noted this phenomenon using a prism in 1666 and published his observations in 1672. In the early 1800's, the spectroscope was invented by Josef von

Fraunhofer. By placing a slit in front of the prism, he found that the solar spectrum was interrupted by many dark lines. At first it was not understood what caused these gaps. Later it became clear that these were caused by elemental gases absorbing specific frequencies of light. This one fact is all one needs to understand why a SHG is a useful instrument. Spectroscopy in one form or another is the main tool of modern astronomy.

Background History of the SHG

Unlike many inventions the origins of which are lost to Father Time, we know exactly when the idea of the SHG came into being. Frenchman Pierre ("Jules") Janssen went to India to study the total eclipse of the sun on August 18 1868. He attached a spectroscope to his telescope to try to determine the gas composition of prominences. Sure enough, he was able to discern that most of the glow was from the hydrogen line at approximately 656 nm. He later stated the following

Cette méthode consiste, dans son principe, à isoler dans le champ spectral un des faisceaux lumineux émis par la protubérance, faisceau qui est déficient dans la lumière solaire, et à transformer ensuite les éléments linéaires des images protubérantielles dans les images elles-mêmes, par un mouvement rotatif assez rapide imprimé au spectroscopie.

In principle, this method consists in isolating, in the spectral field, one of the light beams emitted by the prominence, a beam which is deficient in sunlight [light from the solar disk], and then transforming the linear elements of the prominence images into the images themselves by a fast rotating movement imparted to the spectroscope.



Henri Alexandre Deslandres and the spectroheliograph at Meudon Observatory

he uses rapid movement of spectroscope to pick off a small segment of the sun and then build an image of the complete disk. About 20 years later, nearly simultaneously George Ellery Hale in the U.S. and Henri Alexandre Deslandres in Meudon, France built the first spectroheliographs. Hale is more famous as the large telescope impresario who built the 40" refractor at Yerkes, the 60" and 100" reflectors at Mt. Wilson and the 200" telescope at Mt. Palomar that bears his name, but his major scientific interest was as a solar observer.

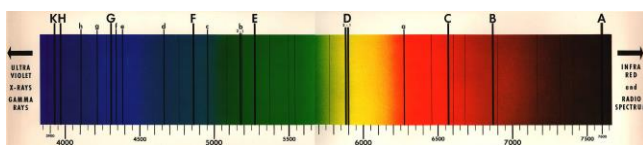


Spectroheliograph at Hale's 150-foot solar tower at Mt. Wilson (completed in 1911)

Most of the development of SHG and SHS until very recently was dominated by 2 countries: France and USA. Indeed most of the developments took place either in California or Paris area. Could it be the wine?

These early devices were rather large and used somewhat complicated mechanical or optical tricks to build a full image of the sun by scanning across the disk. This remained the state of the art for almost a hundred years. There were some amateurs who built SHG/SHS devices based on mechanical or optical scanning methods but their numbers are small and it is considered a somewhat advanced project for the average amateur telescope maker. The one man who is given the most credit for keeping SHG/SHS of these types from ATM extinction is Fred N. Veio, a Californian, who wrote the book *The Spectrohelioscope* in 1991. If you wish to pursue this path this book is a must. It's now out of print but possibly available from used book dealers on the web.

What's important is his last comment, describing how

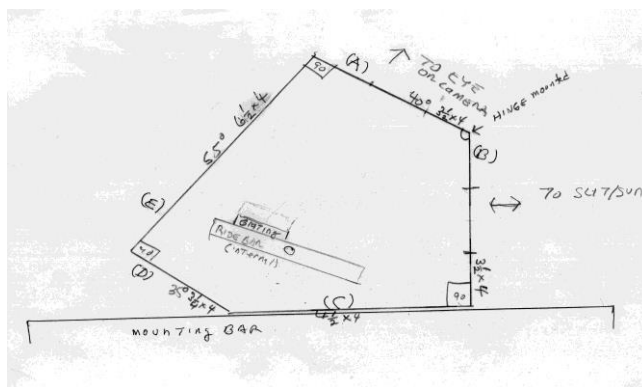


Solar spectrum

We're up to the 1990's and it's time to hop on the plane back to France. By this time CCD chips and computers were generally available. This led to a major shift in thought on how to construct a SHG. Off-load all the mechanical complexity and simulate that part of it on the computer. Instead of mechanically scanning across the image, let the sun pass across the field of the device as you pick off slices of the image, and then reconstruct the full image with a computer. Physically the SHG has returned to its original simple form of a telescope and spectroscope, just like in 1868. And that is what makes it a much simpler task for an ATM'er. You actually don't need to build anything! Get yourself a small telescope and then buy a good spectroscope that you can attach to your scope and you're basically done. There is one minor hitch: a good solar spectroscope can cost a bit of money, and that's why many ATM'ers build their own.

We're almost done with the history but for one missing piece. There was no software developed to merge (quilt) the spectral lines into a full disk image. Then in a lovely Paris suburb in the year 2002 a gentleman by the name of Daniel Defourneau created a spectral line merge program called SpecHelio Bas. He attached an ordinary webcam to his SHG and captured an avi sequence to feed through his program. The modern digital SHG was born. Shortly after, another Frenchman Christian Buil repeated the same feat.

And that's more or less where we stand today. Like so many other things, some of the innovation and progress has in the last few years shifted eastward towards China, Hong Kong and Japan. The most current and commonly-used merge software, the one that I use, is called Slim (spectral line merge) developed by Wah-Heung Yuen (his on-line handle is Wah!). He has also developed a Photoshop sequence to clean up the images for a nicer appearance. This ends the historical portion of the article. I hope it's clear why building a SHG is a more doable proposition for an amateur.



Spectroscope design

Constructing the SHG

Now I will discuss how I built my SHG and then software steps needed to build the final image.

As stated before, a digital spectroheliograph is simply a telescope that has a spectrograph attached to it, with a sensor that captures images and a computer that reconstructs the full-disk image.

I defined certain criteria that I wanted in the design

- Light weight: no more than 10 lbs.
- Ability to scan of full disk of sun: I wanted a general view of sun at a given wavelength.
- Made with easily available parts to keep cost reasonable (<\$500).
- Somewhat adaptable: ability to swap gratings for resolution and the ability to swap out lenses for wide or narrow views.

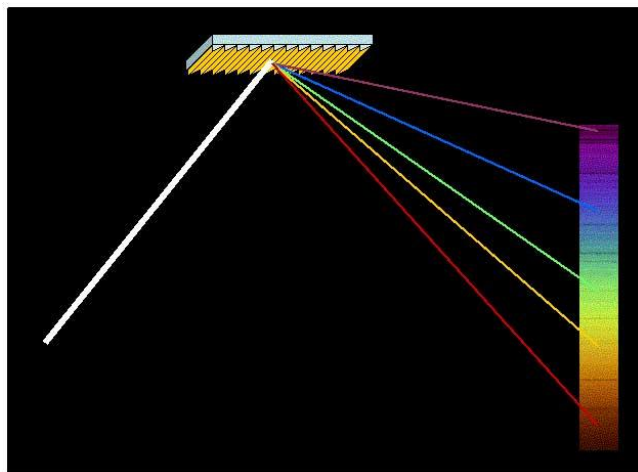
So here is the order of components in a SHG and the considerations and decisions I made. I strongly suggest that you visit the websites listed at the end of the article and see how other ATM'ers built their SHGs. In some cases you may find those simpler than my solution.

1) Imaging telescope: This is what projects the image of the sun's disk onto slit of the spectroscope. What I had to consider was the solar disk image size in mm. The image size is important because if you want to image the entire disk it has to be smaller than the length of the slit. The slit I use is 6mm long. I decided on a 50mm binocular lens with 300mm focal length, which gives a disk image diameter of approximately 3 mm (the formula is $FL \times 0.00948$). Also a 50mm lens has roughly same resolution as a Lunt 50mm solar scope. What is somewhat unique in this telescope is the focus. It is done simply by manually push or pulling the objective lens forward in the telescope body.

2) The spectroscope: This is what separates sunlight into its component colors. It is a bit more complex than an imaging telescope and is made of the following components.

a) The slit: this is what is needed to create the spectral lines. There are 2 main considerations. Slit length and slit width. The length determines how large a disk you can handle. The width plays the most important part in spectral resolution. For solar work it is recommended that the slit be about 15-25 microns wide. I had a lot of help with this from spectroscopy expert Ken Harrison. I decided to purchase a variable glass slit wheel that you can set from 100 to 20 microns. I use the 20 or 25 micron setting. Some ATM'ers make their own slits. I decided that would add a lot of work. So I paid the \$65 and got a commercially made one.

b) Collimating scope (lens): This is what takes slit image and converts it to parallel light rays needed by the grating. I used another 50 mm lens with 200 mm focal length. There is a rule that the f/ratio of a collimating lens should be same as that of the imaging telescope. I solved this by placing a baffle in the collimation tube to increase the f/ratio . What is of paramount importance is that collimation lens is focused onto the slit as accurately as possible. If this not done properly, the images will be blurry no matter how perfect the rest of the system is focused.



The diffraction grating

c) The holographic (or ruled) grating: this is what converts white light to primary colors. There are 4 things to consider here.

Size: I used 50 x 50 mm square or 35mm by 35mm.

Lines per mm: this determines resolution in Ångströms (Å). The most common gratings are 1200, 1800 or 2400 lpmm. The more lines, the better the

resolution, but the trade-off is that the spectrum is dimmer. An 1800 lpmm grating gives about 0.64Å resolution and a 2400 lpmm grating gives 0.35Å . I have a 1200 lpmm grating that is useful in the infrared, where longer wavelengths are still resolvable with less spread.

Type: Visible, UV or Infrared. The gratings are optimized for specific wavelength ranges. Most users use Visible which has near UV and near IR anyway. I got an IR grating for extended IR lines. UV is less useful since the Earth's atmosphere cuts off most UV light anyway. Visible gratings are centered at around 500nm (green), while the center of an IR grating is at 1000 nm.

If you can only choose one grating, I recommend a 50 by 50mm 1800 lpmm visible type. It works for most cases and is a good balance. The cost is \$200-\$300.

d) Imaging lens/telescope: This scope recombines parallel light rays from the grating back into an image of the spectrum. In my case I used another of the same lens (50mm by 300mm) as sun imaging telescope.

I strongly recommend that you look at other examples of SHG's built by others. I am known as the "Junkyard Astronomer" at the WAA club. My SHG was built using plastic and cardboard tubing, pine wood, tape, hose clamps, etc. It's not pretty, but it does work. What is important is that the components are aligned and centered properly. You can skip my building plans if you have decided on another type of device.

Construction details

The easy part: Imaging telescope(s) for sun and camera.

1) Imaging camera scope: I used 2 inch mailing tube cut to 9 inches in length. At one end I used $1\frac{1}{2}$ inch compression plumbing fixture and a drawtube $3\frac{1}{4}$ inch long. The interior of the tube should be sprayed black (all interior body parts are sprayed black to eliminate reflections). The 50mm lens needed a bit of Scotch tape around the outside until it was snug. Carefully place the lens in the tube and make sure its square (no tilting). Focusing is done by moving draw tube up and down.

2) Imaging sun scope: I used 2 inch PVC pipe cut 12 inches long. Since I decided I was going to lock the scope body to the slit box, in order to focus I would need to move objective lens manually inside the tube. I built a 2 inch lens sleeve that slides the lens inside the tube with just enough friction to move easily, but

not so easily that it would slide under the force of gravity. I also placed a lock screw in center range of focus to lock the lens once it was focused. The other end of tube I placed a 2" to 1¼" eyepiece adapter and two 1 inch brackets. These are used to lock the scope body onto the slit box.

The harder part: the spectroscope.

1) The slit holder box and collimator: The slit holder box is made from two 4" x 4" x ½" pieces of pine. They are connected by four 3" ¼ x 20 screws. The front part has a centered hole with a 1¼ diameter 2 inch long copper tube glued into it. This is where the imaging telescope will be located. The imaging scope is then screwed to the wood. The back part of the slit box contains the slit and collimator tube. I drilled a centered 1 inch hole. I will not discuss the exact mounting procedures for my glass slit since every slit varies in design type, and so you will have to craft your own mounting. The slit should be centered as best as possible. The collimator is located at the back end of the slit box. It is composed of 2 tubes that slide one inside the other. One of those tubes is glued to the back of the slit box. Make sure it is centered as best as possible to slit hole. The other tube contains the 50 mm diameter 200 mm focal length lens. The lens tube is moved until the focus point of the lens touches the slit. The lens tube also has a hose clamp to lock the tubes in place once perfect focus is achieved. One thing to consider is that the slit must be at the proper angle to the grating. The whole slit box and collimator unit can be rotated once inserted into spectroscope body. I placed a mark on the slit mounting once I located the correct position. There is 1 inch gap between the 2 pieces of wood of the slit box. This gap is covered by Velcro strips which can be quickly removed or reattached. This gap allows me to inspect for dust and permits visualization of the sun's image so I know its position relative to the slit. Once I know that the sun is aligned properly I close the gap with the Velcro strips to keep dust and stray light out as much as possible.

A note on slit cleaning: One weakness in the SHG design is keeping the slit free of debris. If any particles get on the edge of slit they will project shadows onto the image in the form of dark lines call *transversiums*. While it is possible to remove these shadows using software, it best to avoid them altogether. Open slits are cleaned by blowing air and hopefully knocking off the particles. One reason I chose a glass slit is that it is sealed. But even a glass slit can get

dirty and may need to be cleaned. One method I use is to place the slit wheel under a low power binocular microscope. Recall that the slit is only 20 microns wide! I clean the surface with a Q-tip using distilled water and alcohol. I do not recommend cotton on open slits since the edge may grab the cotton fibers.

2) Main grating spectroscope body. This was the trickiest part. The main concern here is to achieve the correct angle so when you scan the spectrum all of it is there to record. It's best to refer to the "Spectroscope design" diagram on a previous page to understand what I did. The body of the spectroscope is in the shape of an irregular pentagon. I started by cutting 2 identical pieces (parts A and B) of 4" x 3½" x ½" pine, then cutting a center hole in each about 40 mm in diameter. The trick I used was to attach the pine pieces with 2 hinges. Then I made the bottom (part C), a 4" x 4½" by ½" piece of pine. Take note that part B and part C are attached at a 90 degree angle. Part B is where light from the collimator comes in. This is the input port that will illuminate the grating. Part A is the output port where one can observe or record the spectrum. Part D, 4" x 3¼" x ½" pine and part E, 4" x 6" x ½" pine are needed to complete center of box body.



Grating mount

3) Mounting the grating element. Warning! Holographic or ruled reflective gratings are the most easily

damaged optics I ever had to work with. Pulling off and cleaning a SCT corrector plate is a walk in the park in comparison. Once contaminated they cannot be cleaned! I grew up in New York City and there is a Yiddish word called *schmutz* (basically, dirt). If you touch the surface with your fingers, you get *schmutz*! If you try to blow off dust with your breath, more *schmutz*! The only way to blow off dust is to use rubber bulb-type blower. If you use canned air, *schmutz*! You must handle the grating on by back and sides. If you remove the grating from the spectroscope and/or swap it out for another one you need to create a cover or small storage box where the surface is not touching anything. You cannot wrap it even with the finest optical paper or else *schmutz*! (Note: transmission glass gratings are not quite this sensitive.)

There are 2 things to consider when mounting. The grating needs to be able to rotate on its central point so the spectrum can be squared to the slit. Some people get around this by setting up the direction of grating first and then building the other parts in relation to it. The grating needs also be able to move up and down relative to the slit to select the wavelength.

I mounted my grating on a foam wheel that is slightly larger than the grating's longest diameter. In the center of this wheel I placed a screw that is long enough to go thru a riding board and be tightened with a wing nut. The screw head is glued to the wheel so it doesn't slip. I then placed 4 felt tabs on the wheel and I attached the grating with some Goop, a type of glue that you can pull off if necessary. All grating are marked with a "→" that should point in the direction towards the camera side). On the side of the grating I glued (very carefully or you'll get *schmutz*!) a small square of foam that allow me to rotate the grating without touching the glass. The grating and wheel are mounted onto a riding board, which is simply a piece of half inch pine. A hole is drilled at the proper position so the grating gets illuminated as fully as possible. On one edge of the riding board a tapped hole is drilled for a thumb screw and on the other side a tapped hole is drilled for wing nut/washer screw.

Recording an image

To record image you insert a webcam type of camera (it can be color or monochrome; planetary imaging cameras work well, are inexpensive, and you can use them to do planetary imaging too) into the imaging lens/telescope of the spectroscope, focus and record the passing image of sun until complete.

There are many details about operating the SHG that need to be considered and executed properly.

Calibrating the spectroscope: Note: the sun imaging scope is not needed or used for this portion.

1) Squaring the slit to grating: Place an eyepiece in imaging lens/telescope. Point the slit part of spectroscope to sun. Hopefully you should see some pretty rainbow portion of the spectrum. This image should have a nice square look to it. If it does not, rotate the slit/collimator portion until the image's sides are parallel. If you have problems getting a nice orthogonal image your grating may be slightly angled. Rotate the grating left or right and check again. Repeat until you get that nice rectangle.

2) Focusing the slit on the collimation lens: This is very important and I spent a lot of time on this step! There is a cute trick to do this that I was taught from David Groski, a Stellafane award winner. Take the imaging/camera telescope with a good medium eyepiece out at night and focus on some stars until the images are pinpoint. This means you are now focused at infinity. Lock up the focus so it stays at infinity. On the next sunny day place the imaging scope back into spectroscope. Point the slit at the sun until you see that rainbow and look very carefully at the edges without changing the position of the eyepiece. The edges should be sharp. If they are not, increase or decrease the distance of the collimating lens in relationship to the slit. Once you get really sharp edges, lock down the collimation lens. Treat your device gently so that hopefully you won't need to do this again!

3) How to select wavelength: This may vary with design. In my unit I select the wavelength by tilting the grating forward and backward until the color/absorption line you want is centered. Then I lock down movement with a wing nut. You will need to learn where the important absorption lines are in the spectrum. You can find tutorials on the Internet or books on the subject.

4) Focus the absorption lines using an eyepiece (when visual) or the camera. Focused absorption lines appear as sharp as possible. This may have to be repeated if you select another wavelength.

Once the spectroscope is in good position and focused it is time to learn how to focus the sun's image. This requires that the sun imaging scope is attached to the spectroscope. Focusing is done visually or with the camera. If you are imaging in the UV or IR regions you must use a camera unless you have the eyes of a

bee!

Move the SHG unit until the disk of sun is on the slit. You will see a bright beam of colorful light flood into the slit area. The beam will start as a thin line and get wider as maximum diameter of the sun increases. When it's at maximum diameter, observe the edges of the beam. Focus until the edges are as sharp as possible. You have to act quickly because the sun will pass maximum size unless you have tracking capabilities. Once those edges are sharp, you're focused. Note that if you change frequencies you may have to refocus.

Creating an image sequence

I recommend that you mount your SHG on an equatorial mount even though tracking is not needed or used. This will allow for a nice straight drift of the sun across the slit.

- Make sure the camera is focused as described above.
- Set up recording software supplied with your camera, or other video capture software that you like. I use a Point Grey Chameleon camera set to 640 x 480 pixels, in video (avi) mode) at 15 frames per second. The frame rate is important because we are using the rotation of the earth as our scanner so this will determine how many total frames we generate which in turn effects the (Slim) program results.
- Set the shutter and gain control to manual mode. Vary these until the spectrum near your absorption line is bright but does not overwhelm the line itself.
- Move the SHG westward ahead of the sun until you're just a few seconds ahead. The beam will disappear. Lock the mount and leave the SHG alone.
- Wait until you see first hint of light from sun and hit the record button.
- Keep recording until the last of the sun beams disappears.
- You are now done recording and should have an avi file that is about 1.8 gigabytes in size (1900-2100) frames, ready for processing.

Processing the avi file varies depending on what software you use. I recommend you read chapter 8 in Ken Harrison's book for more information. The Digital SHG concept made building the hardware simpler, but some of the pain is now transferred to the computer. I will describe only the most basic sequence to get a decent image. Some SHG users do all kinds of fancy

processing tricks to get real clean images. There is a long learning curve here. I recommend you read Wah!'s documents on the SolarChat forum on how to process SHG images.

Processing a SHG image is unique in the astro imaging world because it combines elements of both planetary and deep sky image processing as well as steps that are unique to SHG imaging itself.

1) [VirtualDub](#) (free) -- this is used to strip off most of avi frame except a small area around the absorption line. This is a pre-processing step required by Slim software.

2) [Slim](#) (free) - this is the program that builds the image of the sun from all those frames of the absorption line. This program is what makes SHG possible.

3) [Registax 6](#) (free) this is used to sharpen the image from step 2. This is similar to planet image processing except for one important difference. Wavelet processing is done from bottom slider (#6) up and NOT from the top (#1) down. The reason is that we only have a stack of one and you will get horrible noise if you use low numbered wavelet sliders.

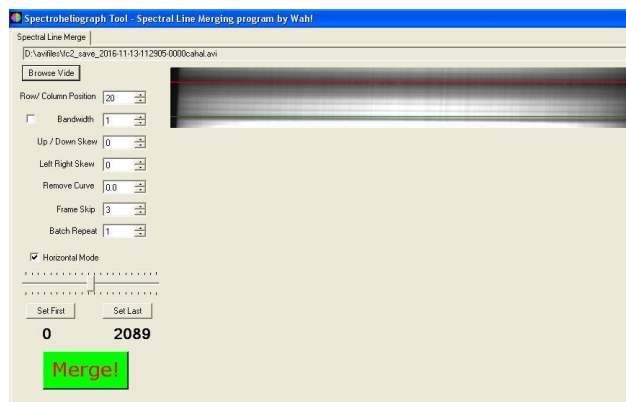
4) Photoshop/or other photo processing software (expensive to free depending on which one you use). At a minimum we need the ability to rotate and resize the image. A raw SHG image of the sun is in the form of an ellipse and needs to be rounded. This is normal and results from spectral stretching. At this point it's as much an art as a science. Here it becomes similar to deep sky processing including using flats, noise removal, etc. This aspect of image processing is still in development by various SHG users throughout the world.

A quick guide to the software workflow

1) VirtualDub editing

- Open the video file that you created in the capture step. File/Open video file. Select the video file in the dialog box.
- Under Video -select Filters - select "Add" and choose "null transform" then "OK." Then select "cropping." A pop-up appears. Slide the frame selection bar at the bottom until the spectrum is at its widest. Then trim down from top and bottom and leave a little bit of "fat" around the absorption line. Then click "OK."
- Under File select "Save as AVI" and fill in a name of your choice. This file is what will be the input to the Slim program.

2) Slim processing



- Start the Slim program and select 'Browse video'. Select the video that was generated by VirtualDub. An image of the middle of the sequence frame will appear. If the absorption line is not perfectly horizontal or vertical, use the skew radial buttons.
- Hover the mouse arrow over the image. A green line will appear. Place that green line as best as possible to the middle part of absorption line. Click and the line will turn red. That is what will be used to select pixels to build the image.
- Click the green Merge! button. The program will generate the raw SHG image. It takes a bit of time. The image will be in Tiff form with same name as the avi and in same folder.

3) Registax processing

- Open the output file from Slim [Note: My computer seems to have issues when using Tiff files with Registax, so I open the Tiff file in Photoshop and save it as a png file and then I use that in Registax]. Click "Select" on upper left. The navigation pop-up appears. Select the proper file type and select the image file you just created.
- You will automatically be on the wavelet tab. Starting with slider #6, manipulate the image. Use sliders in descending order. Don't overdo it or you get noise and artifacts. This is a trial-and-error step.
- Save the image.

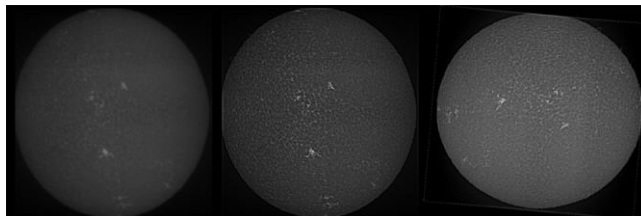
4) Photoshop processing

Note: There are many versions of Photoshop. Many functions are similar but some are different. I use CS3.

- Open the file that was created in Registax
- Look at the image and rotate it until the major axis

of the ellipse is either on the vertical or horizontal axis of the picture frame.

- Select Image/Resize and change image size, making sure 'Constrain Proportions' box is unchecked. Change the width or height until image of sun is as round as possible.



Outputs from (L-R) Slim, Registax, Photoshop

Now you have completed the minimal steps needed to create an acceptable SHG image. There are additional manipulations that will make the image smoother and nicer looking. I suggest reading Wah!'s document on the SolarChat web site.

Making a spectroheliograph is a challenging project, but the instrument will allow you to capture the sun in any wavelength, revealing many different features in on the solar surface and in the sun's atmosphere.

Resources

Daniel Defourneau

<http://www.astrosurf.com/ciodelabrie/sphelio.en.htm>

[Solarchat](#) spectroscopy forum

<https://solarchatforum.com/index.php> (my stuff is in there under the handle 'highfnum')

On SolarChat, documents and software downloads for SHG and other solar stuff, look for user Wah!

The "Solar Reference Library" on SolarChat is at

<https://solarchatforum.com/viewforum.php?f=7>

The most important book on this topic is *Imaging Sunlight Using a Digital Spectroheliograph* by Ken Harrison, published by Springer (The Patrick Moore Practical Astronomy Series) 1st ed. 2016 Edition. It's available as a paperback for \$34.99 and as an [ebook](#) for \$24.99

https://www.gratinglab.com/Products/Supplemental_Information/Cleaning.aspx

What It's Like on a TRAPPIST-1 Planet

Marcus Woo

With seven Earth-sized planets that could harbor liquid water on their rocky, solid surfaces, the TRAPPIST-1 planetary system might feel familiar. Yet the system, recently studied by NASA's Spitzer Space Telescope, is unmistakably alien: compact enough to fit inside Mercury's orbit, and surrounds an ultra-cool dwarf star—not much bigger than Jupiter and much cooler than the Sun.

If you stood on one of these worlds, the sky overhead would look quite different from our own. Depending on which planet you're on, the star would appear several times bigger than the sun. You would feel its warmth, but because it shines stronger in the infrared, it would appear disproportionately dim.

"It would be a sort of an orangish-salmon color—basically close to the color of a low-wattage light bulb," says Robert Hurt, a visualization scientist for Caltech/IPAC, a NASA partner. Due to the lack of blue light from the star, the sky would be bathed in a pastel, orange hue.

But that's only if you're on the light side of the planet. Because the worlds are so close to their star, they're tidally locked so that the same side faces the star at all times, like how the Man on the Moon always watches Earth. If you're on the planet's dark side, you'd be enveloped in perpetual darkness—maybe a good thing if you're an avid stargazer.

If you're on some of the farther planets, though, the dark side might be too cold to survive. But on some of the inner planets, the dark side may be the only comfortable place, as the light side might be inhospitably hot.

On any of the middle planets, the light side would offer a dramatic view of the inner planets as crescents, appearing even bigger than the moon on closest approach. The planets only take a few days to orbit TRAPPIST-1, so from most planets, you can enjoy eclipses multiple times a week (they'd be more like transits, though, since they wouldn't cover the whole star).

Looking away from the star on the dark side, you would see the outer-most planets in their full illuminated glory. They would be so close—only a few times the Earth-moon distance—that you could see continents, clouds, and other surface features.

The constellations in the background would appear as if someone had bumped into them, jostling the stars—a perspective skewed by the 40-light-years between TRAPPIST-1 and Earth. Orion's belt is no longer aligned. One of his shoulders is lowered.

And, with the help of binoculars, you might even spot the Sun as an inconspicuous yellow star: far, faint, but familiar. Want to teach kids about exoplanets? Go to the NASA Space Place and see our video called, "Searching for other planets like ours": <https://spaceplace.nasa.gov/exoplanet-snap/>. This article is provided by NASA Space Place. With articles, activities, crafts, games, and lesson plans, NASA Space Place encourages everyone to get excited about science and technology. Visit spaceplace.nasa.gov to explore space and Earth science!

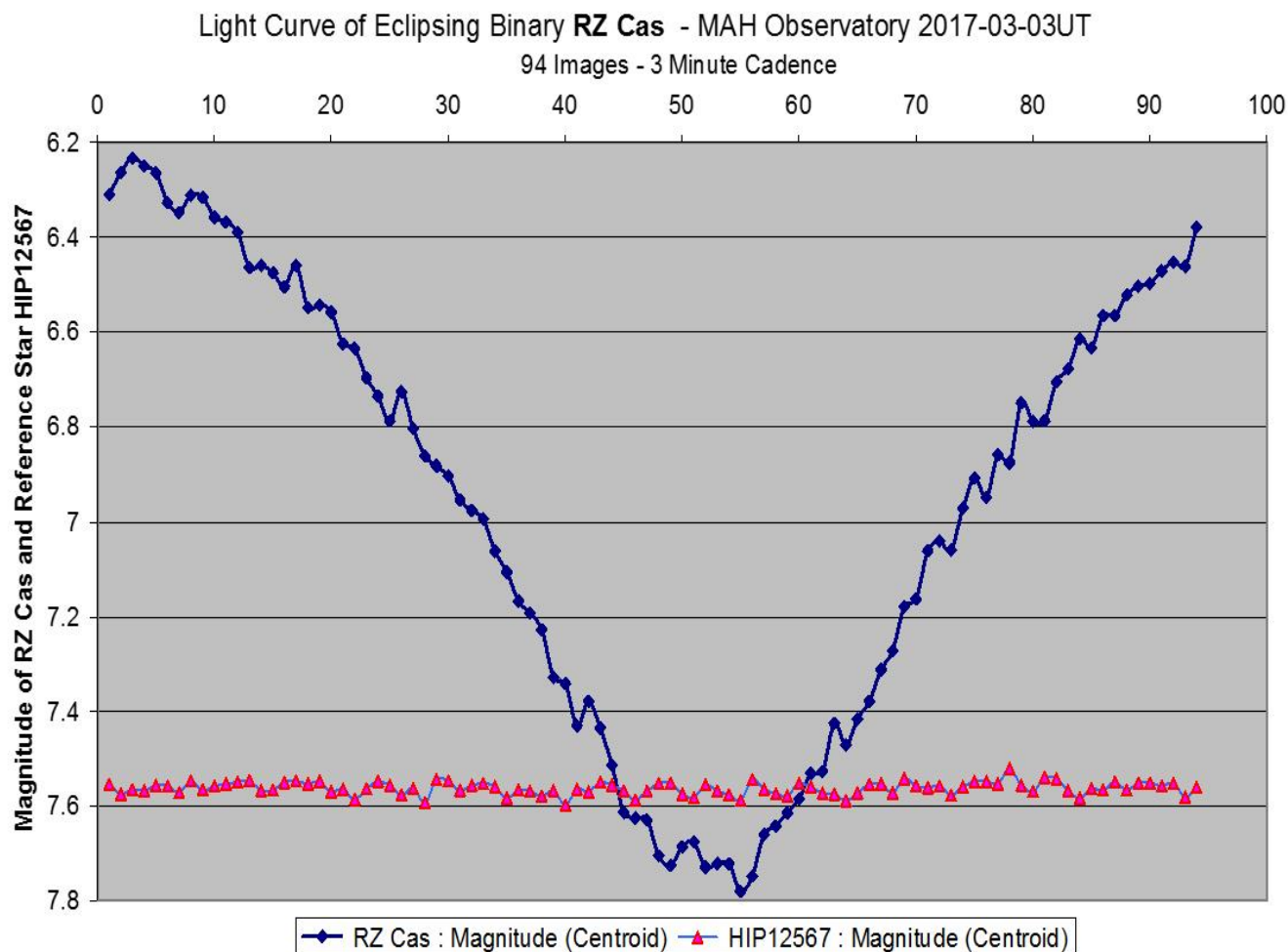


This artist's concept allows us to imagine what it would be like to stand on the surface of the exoplanet TRAPPIST-1f, located in the TRAPPIST-1 system in the constellation Aquarius. Credit: NASA/JPL-Caltech/T. Pyle (IPAC)



Light Curve of RZ Cassiopeia (RZ Cas)

Rick Bria



Photometry Light Curve from the Mary Aloysia Hardey Observatory. The Brightness of RZ Cas was measured from images taken every 3 minutes over a time period of 4 1/2 hours (94 images in total) on 2017-03-03UT using the 85mm refractor, ST10XME Camera, 10 second exposure w/Green filter. Images processed/measured in MaximDL Software and exported to Microsoft Excel.

It amazes me what astronomers can learn from light entering their telescopes. Size, mass, temperature and color of distant stars are just a few examples of information extracted from starlight.

Astrometry is accurately measuring the position of an object in the sky. Mary Aloysia Hardey Observatory routinely measures the positions of asteroids and stars. That information is sent to the **I**nternational **O**ccultation and **T**iming Association (IOTA) as a contribution to *citizen science*.

Photometry is measuring the brightness of objects in the sky. Many stars vary in brightness. Some variable stars do so from processes inside the star. Other

variable stars do so because something blocks the light they emit. I am thrilled to report that the Mary Aloysia Hardey Observatory has achieved a new milestone by accurately measuring the brightness change of the binary star system known as RZ Cas.

A binary star is two stars orbiting each other. RZ Cas is a semi-detached eclipsing binary 204 light years away in the constellation Cassiopeia. Both stars in the RZ Cas system are bigger than our Sun. The two stars orbit so close to each other they complete a revolution in just 1.2 days! Their closeness causes gravity to pull the stars into teardrop shapes. The more massive of the two stars is bright white. The dim, less massive companion star is orange/red. Material is be-

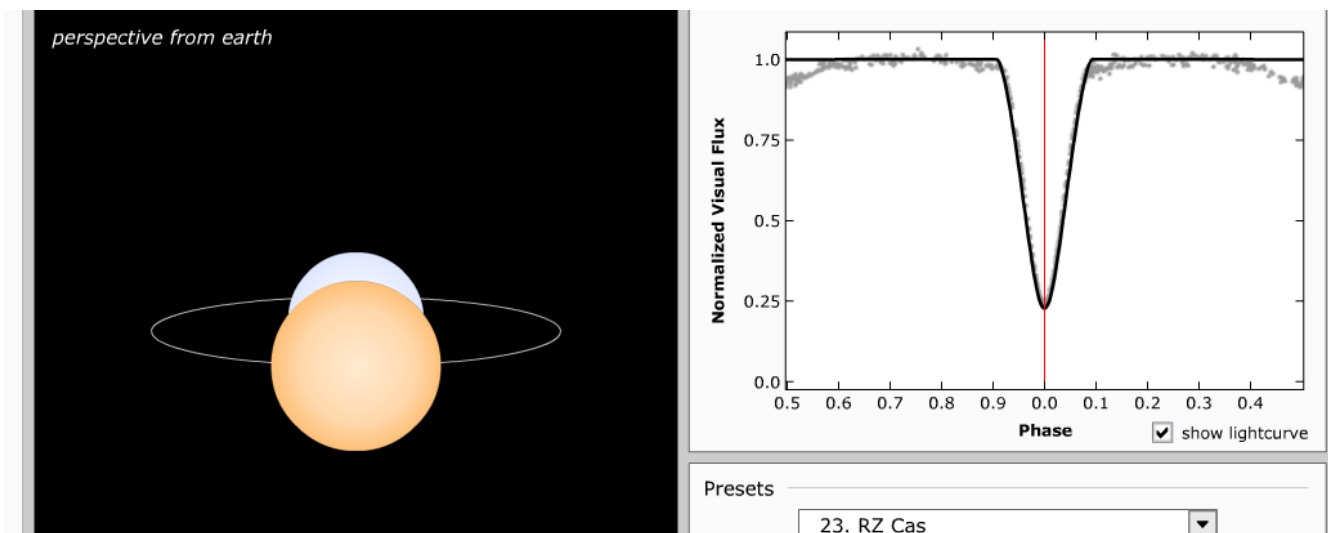
ing ripped from the dim star and deposited onto the more massive bright star. This material transfer puts RZ Cas in the category of *semi-detached eclipsing binary*.

Thankfully, the plane of their orbit causes the dim star to block (eclipse) most of the bright star as seen from Earth every 29 hours. During the 4 1/2 hour eclipse, RZ Cas will slowly dim, then return to its normal brightness. Measuring the total light output from RZ Cas over time creates a *light curve*. The light from a nearby comparison (reference) star of known brightness is also measured. Comparing the *difference* between RZ Cas and the reference star is known as Differential Photometry.

On 2017-03-03 a Differential Photometry test at the Mary Aloysia Hardey Observatory successfully recorded the RZ Cas light curve minima. Starting at 1:10am, 94 images were taken of RZ Cas and reference star **HIP12567** at 3 minute intervals. Image acquisition ended at 5:35am, when morning twilight brightened the sky.

The data was then processed/measured in photometry software (MaximDL) and exported into MS Excel to generate a light curve in the below above. This data will be sent to the American Association of Variable Star Observers (AAVSO).

This was a test, and not all photometry procedures were followed exactly, but the results match with the predicted brightness change of RZ Cas. The measured brightness result was magnitude 6.2 - 7.8 (remember that higher numbers are dimmer in the star magnitude scale). This nearly perfect result is very encouraging. The reference star's data (orange triangle) contains noise. The magnitude varies slightly. This noise level was better than expected for this test. Even so, I think I can reduce noise by a factor of 3 going forward. If achieved, this could allow more types of photometry events to be targeted. ExoPlanets could theoretically be within reach.



Simulation graphic above of the RZ Cas system produced using the online eclipsing binary star simulator at <http://astro.unl.edu/naap/ebs/animations/ebs.html> NOTE: The simulator assumes stars are spherical. It does not show the teardrop star shapes of RZ Cas.