Wayne State Solar Observatory located at Lake St. Clair Metropark

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Contents

Abstract

A good way to excite members of the community towards the science, technology, engineering and mathematic (STEM) fields is through outreach within the community. The younger members of the community may one day be the future research scientists and educators and are perhaps the most likely to be intrigued by what science has to offer. As kids venture through the education system they are exposed to STEM in many ways. However, most academic administrations set specific curriculum which must be followed. These courses of study may not always allow time to explore the vast importance of STEM in this era. Through outreach we hope to capture the minds of the community, especially children, in hopes that they will feel inspired to pursue and support STEM. Astronomy is often a gateway to interest in the STEM fields. By granting access to a public observatory and other resources, we aim to open the doors of exploration to those in the region who may not otherwise have the opportunity.

1 Introduction

We set out to build an observatory located at the Lake St. Clair Metropark for the purpose of outreach. Several goals were set at the beginning of the project which will continue to be worked on after this Research Experience for Undergraduates (REU) program. The main goal is build a functioning autonomous observatory to educate and provoke interest in astronomy and create a gateway into the STEM fields. This year we planned to start by emphasizing solar observations as opposed to night sky observing. Other objectives include accumulating a database of information for use in outreach programs for K-12 educators (photos, videos, and other data). There will also be a display that shows a live view of the Sun both at the observing site and online. Finally, Dr. Cinabro plans to submit a grant for the incorporation of a night telescope.

Once the observatory has been built we will publicize and broadcast the existence of the observatory for the use of organizations, administrations and educators. Also, its curators will plan to conduct ten or more interactive demonstrations of the observatory and its workings to K-12 classes in the tri-county area. Likewise, there will be plans for six or more events hosted at the observatory itself. These include but are not limited to K-12 classes, scouting events, and star parties.

I also had several personal goals for this REU. I wanted to gain a deeper understanding of the Sun's processes, solar astronomy and a greater appreciation for the Sun. For this REU I would also need to learn HTML[1] and CSS[2], and any other computer language needed to make the observatory remotely controlled and independent.

2 Equipment

In this first year of creation the observatory will include a Coronado 90mm solar telescope[3]. This telescope is specialized to only look at the wavelength of light given off by singly ionized hydrogen at 656.3Å. This hydrogen emission line is known as hydrogen alpha ($H\alpha$)[4]. Looking at this wavelength allows us to look directly at the chromosphere where features like flares and prominences exist. Images of the Sun will be acquired with a SBIG-8300C cooled one shot color Charged Coupled Device (CCD)[5] camera. This CCD has small pixels, when paired with the moderate focal length of the Coronado optimal solar imaging will be capable. The CCD is cooled which will provide low noise even during hot summer days. The fact that we chose a color CCD will aid us in processing. In addition it will give simplicity to the system as we will not need RBG filters and a filter wheel. At 1.39"/pixel features like filaments will easily be seen; even the smallest sunspots will come be resolved. The telescope will be mounted on a heavyweight German Equatorial Mount (GEM)[6]; a Paramount PMX-PPP[7]. This GEM is rated to hold ninety pounds which will easily accommodate the solar scope and CCD. The telescope system will be housed at the Lake St. Clair Metropark in an automated Durango Skies observatory dome; approximately six feet in diameter.

This equipment will be controlled by a desktop computer stationed at the Huron to Erie Alliance for Research and Training (HEART)[8] lab at the Lake St. Clair Metropark. A large fifty-five inch display is also going to be added into the HEART lab. This display will host a live view of the Sun as seen by the telescope. Also a time lapse play back of images taken by the telescope which will let viewers easily see how dynamic the Sun really is as features change. These images will also be accessible online. Students learning about solar astronomy will be able to examine the solar surface and see features like sunspots, filaments, flares and prominences in real time.

In the future the observatory may be retrofitted with astronomical equipment for viewing night skies as well. With this retrofit, many more possibilities open for the observatory. It would allow for data acquisition almost twenty-four seven, weather permitting. While imaging the Sun only allows for image procurement, and light photographic analysis, a night seeing telescope would allow educators to utilize Lake St. Clair Observatory (LSCO) for much more than solar education. Deep sky objects (DSO's) could then be studied in classrooms who use LSCO. DSO's such as galaxies, nebulae variable stars, binary star systems, novae and even extragalactic supernovae. Methods like plate solving could also be applied which would allows LSCO not only to observe novae and supernovae, but to actively hunt for them among the stars.

3 Accomplishments

This summer I worked with Professor Cinabro on the observatory. Because equipment had not arrived in the first few weeks of the REU, I started by creating a website for LSCO. The home page for the LSCO website is shown in Figure 1. The current URL for the site is motor1.physics.wayne.edu/LSCO.html. It should also be noted that this domain is temporary and it will eventually be given it's own domain.

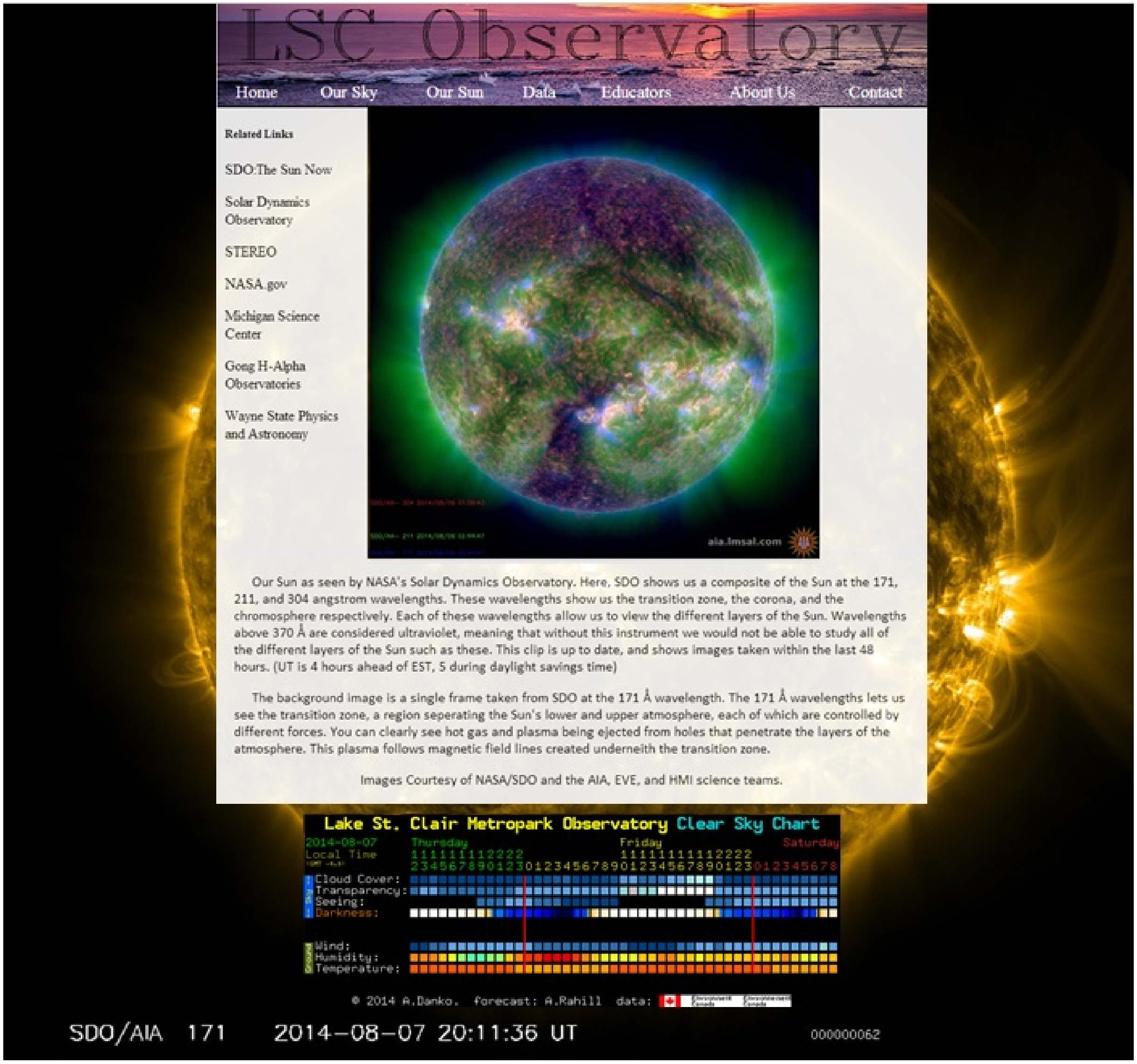


Figure 1: motor1.physics.wayne.edu/LSCO.html

In order to create this website I needed to learn the HTML and CSS languages. Midway through the REU I also needed to learn JavaScript (JS)[9] for us to be able to analyze a database of sunspot information from SILSO (Sunspot Index and Long-term Solar Observations) in order to plot it on the website. During my first two days I had a basic understanding that I would build upon in the following weeks. By the end of the program I'd created a full website with lots of information regarding the Sun. It also has connections to other resources, references, and databases. I also created a few worksheets that teachers could use in an astronomy based classroom setting (See Section 6).The webpage has a lot of real images taken by scientific instruments like SDO (the Solar Dynamics Observatory)[10] and other ground and space based observatories too. These are meant to help students to interpret things they have read or heard about in the classroom. Because the LSCO in this first year was slated to be a solar observatory, much less information is given about other astronomy topics.

I hunted for software that would be able to run data analysis on the images that our equipment would be taking. After a few days it seemed that such software did not exist. I then read several papers about the techniques for image analysis. One in particular *Automatic Sunspot Detection on Full-Disk Solar Images using Mathematical Morphology*[11], was especially important because it actually dealt with Hα images. After contacting one of the authors J.J. Curto, I was able to get the software packages from him. This software is designed to scan images of the Sun and find sunspots on the solar disk; it then totals the sunspots and returns that total. This software is to be used once the observatory is fully operational.

Although I expected to do more during this REU, the program did have some hiccups along the way. That being said, the website itself did occupy all my time and it wouldn't be as developed or possibly may not even have been created had we not had some problems in the beginning.

4 Difficulties

Orders had been placed for the observatory well before I moved to Wayne State University (WSU). After some time we had not yet gotten our telescope, mount, or any other instrumentation. Sadly this put the brakes on the project and forced me to work in other areas. We then discovered that none of the equipment had even been shipped due to vendor approval issues within the department. Even at the end of the REU, we unfortunately hadn't received a camera, telescope, or single wire that would be used in the undertaking.

I also had problems with some of my computer coding. While conquering HTML and CSS was no problem, it was on the other hand hard for me to grasp JS. Being that I had never had a programming class before this REU, I found it very challenging to learn JS; a language usually not taught as the first to a programmer. Luckily JS was only used a small portion in my work, and I was lucky enough to have a friend who is well versed in the language that could help me.

During my time here I also looked into solar image processing and analysis software. I came to find that almost all of the programs written for solar image analysis were meant for images taken by research grade telescopes. On top of that, none of those observatories image in Hα.

After finding the one program, its author J.J. Curto wrote to me and said that the package was written 10 or so years ago and that it would need some updating. He also forewarned us that the comments in the C++[12] code were written in Catalan; a mixture of French and Spanish used in the Catalonia region of Spain. While I wasn't able to tackle this problem, Professor Cinabro and graduate student Rebecca Coles have begun to look over and update the data files.

There is one other problem relating to the sunspot counting software. The daily sunspot count is known as the Zürich (or internation)sunspot number R. R is defined in equation (1), where s is the number of sunspots, g is the number of sunspot groups, and k is an observational reduction coefficient.

$$R = k(10g + s) \tag{1}$$

k is used to correct for observational errors between observatories. On any given day one individual may count s number of sunspots, while another observer might see a number that varies from s. This has to do with observational parameters like seeing[13], transparency[14], and the resolution of the observers' equipment (telescope, detector, etc...). This number makes Zürich number calculations difficult because k is such a subjective value. On top of that, k is always changing with the atmospheric conditions. To find this value, observations will need to be recorded daily and compared to the daily international number; from this k can be derived for our site. While I wasn't required to calculate k, it was important for me to research this topic for other workers in the future.

The sunspot number is important because it allows us to see one of the most important periodic trends on the sun; the eleven year sunspot cycle[15]as seen in Figure 2. This is an important cycle because it is linked to several other cycles that have been observed. These cycles help scientists to understand what is happening in the Sun's interior.

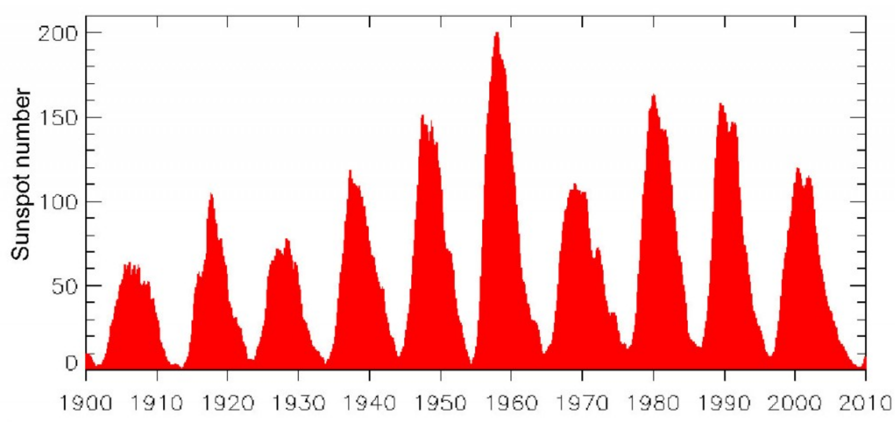


Figure 2: Sunspot Cycle

Although we had some problems, a lot still got done and the project will continue after my REU is over. Whilst I wasn't able to get started on building the observatory, I did lay groundwork for the observatory that is important.

5 Outcome

During the ten week REU program here at WSU work was started for the observatory. While there is still a lot to do, we were able to at least start on the long list of items needed to start the observatory. A decent database of information about the Sun was gathered and a website was created to house this information. In the future the website I created will be home to data retrieved from the observatory telescopes, such as sunspot counts, light curves, and supernova discoveries. Sadly we were not able to start assembling equipment or housing for the observatory. This is most unfortunate for me only because doing hands on work and working with the instrumentation would have been very stimulating. That being said, it was very interesting and I got to work with others who were doing research rather than outreach. It has been eye opening to see how actual research is done and makes me excited to research in the future.

6 Worksheets

Name:_______________

The Sun

The LSC Observatory Website has several helpful images and tools for working on this worksheet, visit at motor1.physics.wayne.edu/~dscriven/Resources.html

What is the Sun?

Discuss the importance of studying the Sun.

The Sun is mostly comprised of what two elements?

The gasses in Sun are ionized meaning they become charged, this means they are known as a the 4th state of matter called ____________?

What nuclear process occurs in the Sun that is the cause of its energy?

If you were to classify the Sun on a *Hertzsprung-Russell Diagram*, what type of star would it be? Based on this, classify the Sun as a dwarf, main sequence star, giant, or something else?

List the layers of the Sun, starting from the core and moving out.

We call interactions between the Sun and Earth space weather. Sometimes the Sun releases large amount of particles into space which interact with Earth. What are these bursts called?

When these ejected particles reach us they interact with our planet, sometimes negatively. Discuss one quite beautiful positive way and one negative way that space weather like this can affect us.

Matter to Energy

Nuclear fusion occurs in the _____________ when _____________nuclei fuse into _____________. The products of this reaction yield less mass than the initial ingredients. Einstein's famous equation _____________ shows us the relationship between matter and energy, and that matter contains large amount of potential energy. Nuclear fusion in the Sun occurs in several steps called the proton–proton chain.

The Proton-Proton Chain

First, two _____________ fuse and create a deuterium particle (made of a _____________ and a _____________), a neutrino, and a positron. The dueterium then fuses with another _____________, and releases a _____________ ray (energy), and a rare isotope of helium, helium-3. It takes two particles of helium-3 nuclei to fuse to create the final product, two _____________ and one _____________ nuclei. Note that the only raw energy released was the emission of a gamma ray. However, you may have seen that another particle called a _____________ was created early in the process. The other name for a positron is antielectron, a positron is really the antimatter version of an electron. They share many of the same characteristics, except a positron as you may have guessed is positively charged. When an electron and its antimatter cousin the _____________ come in contact they annihilate eachother. This happens almost instantly after the positron is released in proton-proton chain process. The annihilation consequently releases energy in the form of an additional gamma ray. In just a single chain of nuclear reactions four gamma rays are emitted. 600 million tons of _____________ is

Name:_______________

Stellar Evolution

The LCS Observatory Website has several helpful images and tools for working on this worksheet. Visit at motor1.physics.wayne.edu/~dscriven/Resources.html

Star Birth

Stars are born in interstellar gas clouds which are composed of mostly Hydrogen and ____________, and a smaller percentage of heavier elements. Clouds that are suitable for birthing stars are generally cold, 10-30 K. This is cold enough for molecules like CO to form. ____________ causes the clouds to contract and begin to collapse. Since ____________ is really a measurement of molecular speed, it is important to mention the low temperature of these clouds. If the cloud is to warm, molecules move rapidly and create ____________ when they bump into eachother. With to much speed in the molecules, gravity can't overcome this pressure, the cloud won't collapse. If the cloud begins to collapse, ____________ starts to create a new inward pressure; pressure that creates ____________. The heat radiates outward as ____________ until the collapsing gas becomes too dense. Eventually the heat becomes trapped, increasing the temperature even more. When the cloud forms into a sphere that can no longer release its internal heat energy, it becomes a ____________. This new object transfers energy to its surface where it can then release light as ____________. The newly forming mass is, however, missing one property that separates it from the rest of the stars in the sky; it must be hot enough in the core to sustain ____________. The star being conceived begins to spin causing the remaining gas around it form into a disk called an ____________. It helps the star gain ____________ until enough has accrued that the force of gravity heats the core to about 10 million Kelvin. Note for later, accretion disks spin very fast, and the friction between the particles causes the disk to emit light and other forms of radiation, and that new stars are not the only heavenly bodies that can have accretion disks. The instant that nuclear fusion takes hold a true ____________ is born. After the birth of the star some of the disk can get pushed away, but often some of it remains. The remaining disk becomes what astronomers call a ____________ short for proto-planetary disk; it will form planets in the future.

Life on the Main Sequence – Low Mass Stars ($< 2\ M_{Solar}$)

Stars come in all shapes and sizes. However, if not enough mass can come together during stellar formation the star will not sustain nuclear fusion and it will fail to be a star.
What name do we give stars that don't get large enough to start fusing Hydrogen? Also, describe what happens to it.

Once a star is born it will spend most of its life on the ____________. (See *Hertzsprung-Russell*) Discuss what types of stars are not a part of the main sequence.

The way a star dies is characteristic of the star's mass. Describe what will happen when a star like our Sun runs out of hydrogen fuel, and what mechanisms lead to this.

Red Giants go through several phases of expansion and contraction. Eventually Helium will be fused to create carbon. The star will not be hot enough to burn carbon in its core. Why?

When the red giant runs out of fuel to burn, it will expel its outer layers as a ____________ and leaves a carbon core behind as a ____________ .

Life on the Main Sequence – High Mass Stars (> 2 M_{Solar})
High mass stars like all main sequence stars get their energy from the Proton-Proton Chain. Stars larger than a few solar masses don't stop fusing at carbon . Once carbon has been created they are also capable of fusion through the CNO Cycle (Carbon, Nitrogen, Oxygen). These stars have an even ____________ burn rate. Stars are analogous to engines in that ____________ stars burn fuel very ____________ while smaller stars burn fuel much ____________. Stars between two and ten solar masses will fizzle out as white dwarves containing carbon and oxygen or even

some heavier elements. The largest stars (> 10 M_{Solar}) continue to fuse elements past carbon and oxygen.

What other element is the final element that resides in the core at the end of a massive stars main sequence life?

When the star’s iron core begins to build up, it slowly stops generating outward pressure. Now that gravity has taken hold, what happens to the star that causes a major cataclysmic event? What is this event called?

Star Death

Violent processes occur to take stars to the stellar graveyard. Left after these explosions are the remnants of these stars, strange objects made almost completely of neutrons. Left behind at the epicenter of the explosive event after the _____________ have been shed; a _____________ is all that remains. It is a crushed core, generally about 20km (12.4 miles) in diameter with a mass of 1.4 solar masses. Imagine shrinking a star more massive than the Sun down to a ball that would fit inside of a major city. Comparable to an ice skater pulling in their arms, the neutron star too tucks in, thus causing it to spin _____________. Some neutron stars have been measured to spin as fast as 1,100 times per second! Aside from neutron stars, stellar death of high mass stars can create an even stranger object... black holes.

What law of physics makes a neutron star spin faster?

Where do black holes get their names from?

If we can’t directly see a black hole, how do we know they exist?

Name:________________

Test Your Solar Knowledge

1. The temperature in the core of the Sun is approximately ____________.
   a) 600 million Kelvin
   b) 15 million Kelvin
   c) 10,000 Kelvin
   d) 1 million Kelvin

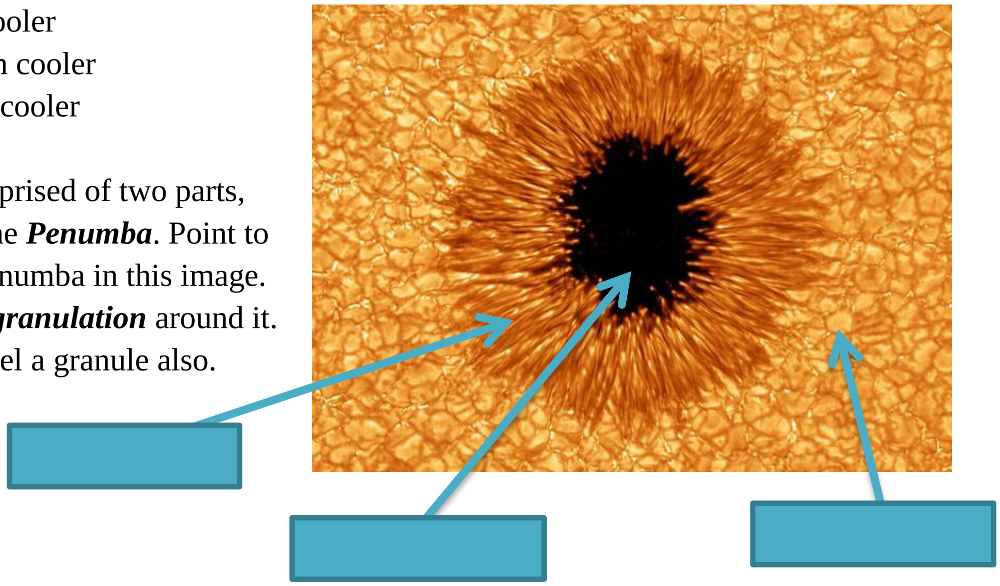
2. What is the temperature of the Chromosphere where sunspots are?
   a) About 6,000 Kelvin
   b) About 1 million Kelvin
   c) About 10,000 Kelvin
   d) About 1,000 Kelvin

3. The sunspot cycle is approximately how long?
   a) 5.5 years
   b) 15 years
   c) 100 years
   d) 11 years

4. On which layer of the Sun do we see sunspots?
   a) The Photosphere
   b) The Convection Zone
   c) The Active Zone
   d) The Chromosphere

5. Sunspots are slightly cooler than the area around them, about how much cooler are they?
   a) 2000 Kelvin cooler
   b) 500 Kelvin cooler
   c) 50,000 Kelvin cooler
   d) 7,000 Kelvin cooler

6. A sunspot is comprised of two parts, the ***Umbra*** and the ***Penumba***. Point to the umbra and penumba in this image. We can also see ***granulation*** around it. Go ahead and label a granule also.



References

[1] HTML, HyperText Markup Language; HTML is a standard markup language for creating website. *http : //www.w3schools.com/html/default.asp*

[2] CSS, Cascading Style Sheet; CSS is used to tailor the look of documents written in markup languages such as HTML. See HTML[1] for reference.

[3] Solar Telescope; a solar telescope is a telescope that specially made to view and image the Sun. Most solar telescopes are telescopes that view the Sun's light, specifically hydrogen alpha[4] *http : //www.optcorp.com/coronado − solarmax − ii − 90 − 90mm − f − 8 − 8 − 0 − 7a − h − alpha − telescope − with − bf15.html*

[4] $H\alpha$ (H-alpha); hydrogen alpha is a distinct wavelength of red light given off by hydrogen. This occurs when an electron orbiting a hydrogen nucleus drops from the third to the second electron shells. *http : //hyperphysics.phy − astr.gsu.edu/hbase/hyde.html*

[5] Charged-Coupled Device; a CCD in the photographical context is an array of photosensative components. These components convert photons into electrons which are then turned into a digital signal. *http : //www.princeton.edu/ achaney/tmve/wiki100k/docs/Charge − coupled*$_d$*evice.html*

[6] Germen Equatorial Mount; a mount used in astronomy that allows the telescope to rotate around the Earth's axis of rotation so that the telescope can follow objects moving in the sky. *http : //starizona.com/acb/basics/equip*$_m$*ounts*$_g$*em.aspx*

[7] Astronomics PMX-PPP *https : //www.astronomics.com/paramount − mx − go − to − german − equatorial − with − pyramid − portable − pier*$_p$*20081.aspx*

[8] Huron to Erie Alliance for Research and Training *http : //www.heartfreshwatercenter.org/?q = WhatWeDo*

[9] JavaScript (JS) is an object oriented programming language. JS generally is used in webpage design to enable interactions between the user and the website. *https : //developer.mozilla.org/en − US/docs/Web/JavaScript*

[10] Solar Dynamics Observatory(SDO); SDO is a space telescope build for study of the Sun. SDO has several detectors that images the Sun's ultraviolet wavelengths, sunspot magnetism and doppler shifts. http://sdo.gsfc.nasa.gov/

[11] J.J. Curto, M. Blanca, E. Martinez, Automatic Sunspot Detection on Full-Disk Solar Images using Mathematical Morphology, Solar Physics, Vol. 250, Issue 2, Page 411-429, August 2008

[12] C++; *http : //www.stroustrup.com/applications.html*

[13] Seeing; in astronomy, seeing is the quality of atmospheric movement. Atmospheric movement causes stars to twinkle and blur, and can cause images to be less resolves. Also see Transparency[14] $http://www.alpo-astronomy.org/jbeish/Observing_Mars_8.html$

[14] Transparency; this refers to the varying "thickness" of the air being observed through. Particles in the air cause light to scatter, which can route photons away from the observer. The size and quantity of particles in the air contribute to this quality. $http://www.astronomyhints.com/seeing.html$

[15] Sunspot Cycle $http://solarscience.msfc.nasa.gov/SunspotCycle.shtml$