

***University of Wyoming***  
*Research Experience for Teachers*  
*H-Alpha 6563 Angstroms*  
*Data Reduction and Analysis of NGC 6946*

***Premise:***

Astronomers today use specialized electronic and computer equipment to determine a variety of characteristics about stellar objects. Without these finely tuned instruments and complex computer programs, our current understanding of the universe around us would be limited to what the human eye can perceive. Distant objects prove especially difficult for the human eye to perceive and can be difficult to reduce even for the professional astronomer. A lot of time and effort by many different professionals is now paying great dividends in understanding what is happening in our universe. Filters that only receive very specific wavelengths of light can be placed on telescopes and the information that is received tells a more accurate story of galactic velocities, star formation, nebular evolution, and much more. CCD cameras millions of times more sensitive than the human eye are now placed on telescopes, super cooled with liquid nitrogen, or liquid helium, and exposed to the deepest, yet dimmest reaches of the universe. Computer programs can now reduce data and give meaningful conclusions about what is being seen in the images.

During this activity, students will be exposed to real astronomical data taken at Wyoming Infrared Observatory (W.I.R.O.) in Laramie, Wyoming home of the University of Wyoming. (Data from other facilities will work.) The students will be given access to the latest technology (MaxIm DL 4) and asked to reduce the given data and come to conclusions about their data based upon given criteria. Specifically, the goal is to find areas of star formation within the galaxy NGC 6946. This is ascertained by taking exposures in H-Alpha and in what is known as R-Band or the visual spectrum. R-band is approximately 20 times wider than H-Alpha. Then through various procedures the R-band will be subtracted out of the entire picture leaving only the H-Alpha. H-Alpha emissions indicate areas of star formation and demonstrate that the students have achieved the goal.

***Purpose:***

To introduce students to the concept of spectrum analysis of stellar objects.

To introduce students to the technological skills required of astronomers.

To introduce students to the concept of filters and why they are useful.

To introduce students to the concept of reducing data.

To give students the opportunity to work with technology and gain experience in the field of astronomy.

**Wyoming State Science Standards Addressed:**

### **Standard 1:**

In the context of unifying concepts and processes, students develop an understanding of scientific content through inquiry. Science is a dynamic process; concepts and content are best learned through inquiry and investigation.

#### ***Benchmark 9:***

##### **Origin and Evolution of the Universe**

Students examine evidence for the Big Bang Theory and recognize the immense time scale involved in comparison to human-perceived time. They describe the process of star and planet formation, planetary and stellar evolution including the fusion process, element formation, and dispersion.

#### ***Benchmark 12:***

##### **Forms and uses of Energy.**

Students investigate energy as a property of substances in a variety of forms with a range of uses.

### **Standard 2:**

Students demonstrate knowledge, skills, and habits of mind necessary to safely perform scientific inquiry. Inquiry is the foundation for the development of content, teaching students the use of processes of science that enable them to construct and develop their own knowledge. Inquiry requires appropriate field, classroom, and laboratory experiences with suitable facilities and equipment.

#### ***Benchmark 2:***

Students use inquiry to conduct scientific investigations.  
Ask questions that lead to conducting an investigation.  
Collect, organize, and analyze and appropriately represent data.  
Draw conclusions based on evidence and make connections to applied scientific concepts.

#### ***Benchmark 3:***

Students clearly and accurately communicate the result of their own work as well as information from other sources.

#### ***Benchmark 4:***

Students recognize the relationship between science and technology and the role of technological design in meeting human needs.

### **Standard 3:**

Students recognize the nature of science, its history, and its connections to personal, social, economic, and political decisions. Historically, scientific events have had significant impacts on our cultural heritage.

#### ***Benchmark 2:***

Students explore how scientific information is used to make decisions.  
The role of science in solving personal, local, and national problems.  
Interdisciplinary connections of the sciences and connections to other subject areas are careers in science or technical fields.

### ***Goals:***

Students will be able to use technology to address given astronomical data and come to meaningful conclusions.  
Students will be able to discuss what filters are and why they are used.  
Students will understand the Hubble Constant and how it applies in determining a galaxy's distance.  
Students will be able to discuss what a sky flat and bias exposure are and why they are important to astronomers when taking data.  
Students will be able to discuss specifically areas in nearby galaxies with observations of star formation based upon Hydrogen Alpha emissions.

**Entry Level:**

Students will need an in depth lesson on telescope technology, filters, and the science behind taking astronomical data with a CCD.

Students will need to understand what a CCD is and how it works.

Students will need to understand the Hubble Constant and how red shift is determined.

Students will need to be able to understand basic computer instructions and apply them as necessary.

Students will need to understand the spectrum of light as it applies to this lesson.

Students will need to understand what a sky flat and a bias exposure are.

**Supplies:**

MaxIm DL 4

Data on CD-ROM of NGC 6946 (Specifically, H-Alpha filter 6563, & R-Band filter, exposure times 300 s for H-Alpha, & 30 s for R-Band)

Access to computer terminals with MaxIm DL 4

Calculators

**Pre-Activity Instruction:**

*Ask:*

Ask students how astronomers determine what stars are made of.

Ask students what they know about the spectrum of light.

Ask students what they know about how astronomers use electronic equipment to collect and analyze data.

*Instruct: Edwin Powell Hubble*

Astronomers look at distant objects and see the same thing as you and I do. How do they know what a star, galaxy, or any object is made of? The answer is by spectrum analysis. The light that we see with our eyes is made up of an infinite amount of components. When you look at a light bulb for instance you see a yellowish white color. But if you take a prism and pass that same color of light through it, the light gets split according to its energy level or wavelength. Blue light is the highest energy light that we see so it is bent the most and red light is the least energetic so it gets bent the least. What you are seeing is all of the colors that make up white light. Rainbows are a natural occurring phenomenon created when nearly perfectly spherical raindrops act like a prism and spread the light from the sun out into a visible spectrum of light.

There is a special tool that astronomers use called a spectrometer. A spectrometer is capable of spreading this spectrum of light so that astronomers can look at the fine details. Since each element and molecule burns with a unique signature and those signatures have been verified here on Earth, astronomers can simply compare what they see in the spectrometer with a chart of the signatures of the elements or molecules.

Astronomers use this tool to look at any light-emitting or light-reflecting object to determine what it is made of. This is how astronomers can identify the different elements or molecules that surround stars, make up galaxies, or simply what a rock on Mars is made of.

Why is this important? It is important to astronomers to know what stars, galaxies, and even rocks are made of because it helps us to better understand how this universe that we live in works. There are many great implications from how and when galaxies formed to where heavy elements such as iron, silicone, and oxygen came from. Understanding the evolution of the universe, galaxies and star systems is understanding a

little better, where we came from and what our star system can expect in the future.

*Ask:*

How do astronomers know how far away things are?  
Who was Edwin Hubble?

*Instruct: The Hubble Constant-Galaxies, The Universe, and Expansion*

In 1929, Edwin Powell Hubble derived what is today known as the Hubble Constant. During this time there was a fierce scientific debate concerning the size of the universe and specifically whether the galaxy we live in (the Milky Way) was the entire universe or if it was just one of many galaxies that comprise a universe. Looking at evidence from observations of “fuzzy” objects known as nebulae, that were not stars, gas nebula, or comets, Hubble discovered that these “fuzzy” objects were actually not in the Milky Way, but many light years out of it and furthermore these objects were not Nebulae, but other galaxies some like the Milky Way and others nothing like the Milky Way. Just how many was a problem because there was no method of determining distant objects other than the rather rudimentary parallax formulas that were based on simple geometry. Hubble derived a formula that allowed astronomers to determine distances of extra-galactic objects. The equation he derived is  $V = H_0 r$ . This means that the recessional velocity ( $V$ ) equals the Hubble Constant ( $H_0$ ) multiplied by the distance ( $r$ ). The Hubble Constant was determined by observational data and is still debated based upon infrared and Hubble Space Telescope observations of Cepheid Variable Stars, and Super Nova explosions. Estimates vary from  $57 \pm 4 \text{ km s}^{-1}/\text{Mpc}$  to  $83 \pm 13 \text{ km s}^{-1}/\text{Mpc}$ . To simplify, when looking at distant objects, almost always the more distant the object the faster its recessional velocity. This discovery revolutionized the world of observational cosmology and opened the minds of many scientists to the vastness of the universe and the sheer numbers of galaxies and thus stars in the universe. Today we know that there are approximately 120 billion galaxies in the visible universe. That number is by no means fixed.

*Instruct: Red Shift & Blue Shift*

Another implication to Hubble’s work is that not only are distant galaxies moving away faster, but the light that we see from those galaxies that is sometimes billions of years old, is more red than galaxies that are closer in a phenomenon similar to the Doppler Effect, called Red Shift. Essentially, because of the high recessional velocities of distant galaxies, the light seen is stretched and appears red. The opposite is found when galaxies are approaching each other at high velocities and the light is compressed and appears blue. (Note: The colors red and blue are not to be construed literally, but are to be understood as whatever color of light observed within the light spectrum, visual or not, is made to appear as a longer wavelength in the case of red shift and a shorter wavelength in the case of blue shift.) This allows astronomers to very accurately measure distances to extra galactic objects and determine what is happening within these galaxies base upon the wavelengths of light observed and how much they are red or blue shifted.

*Ask:*

Why is a camera better than your eye? Why or why not?

*Instruct: CCD Cameras*

Starting with Galileo Galilei, astronomers looked through a series of lenses at an image on a mirror to observe visible light. The human eye is an excellent piece of evolutionary work, but it is relatively ineffective at gathering dim light and totally ineffective at detecting high and low energy light such as x-rays or radio waves. When looking at distant

objects, very few photons reach the retina of the human eye. For example, the closest galactic neighbor to the Milky Way of any size is Andromeda. It is approximately 2.5 million light years away. If your eye was sensitive enough and you could detect the entirety of Andromeda, it would appear as an object seven times larger than the moon appears in the sky. Because it is so dim, (yet still visible), seeing distant or dim objects requires electronic eyes that are very similar to current day digital cameras. These cameras are very sensitive to light because they are surrounded by a very cold median of liquid nitrogen or liquid helium. This allows the CCD camera to detect photons of light from distant and dim objects that are impossible to see with the human eye. If attached to large telescopes or on telescopes in space, they are very effective at collecting light. As effective as CCD cameras are, they are equally complicated and sensitive and require constant care and upgrading.

CCD cameras have a built in signal that shows up as a form of electronic noise that shows up in the picture as static. This static or noise must be subtracted from the digital picture by taking a series of what is called bias exposures. This is accomplished by taking a series of short exposures without opening the telescope cover. A minimum of 10 bias exposures should be taken to ensure that this noise is completely removed. MaxIm DL 4 will perform this operation, but in real astronomy this process is a bit more complicated.

Another important piece of information is what is called the sky flat. Telescopes are usually placed on tops of mountains as far from civilization as possible to avoid the light pollution from city lights. Even though these precautions are taken, random photons of light emitted by distant sources, can reflect off dust, clouds, the atmospheric gases, or the telescope dome. By taking these sky flats you can later divide out this real light noise from your image.

### ***Activity: Investigation of Star Forming Regions in NGC 6946 with H-Alpha (6563 Å) Filter***

Students may work in groups of two, but individual work is preferred. The process reinforces the terminology and concepts required to truly understand what is happening and why.

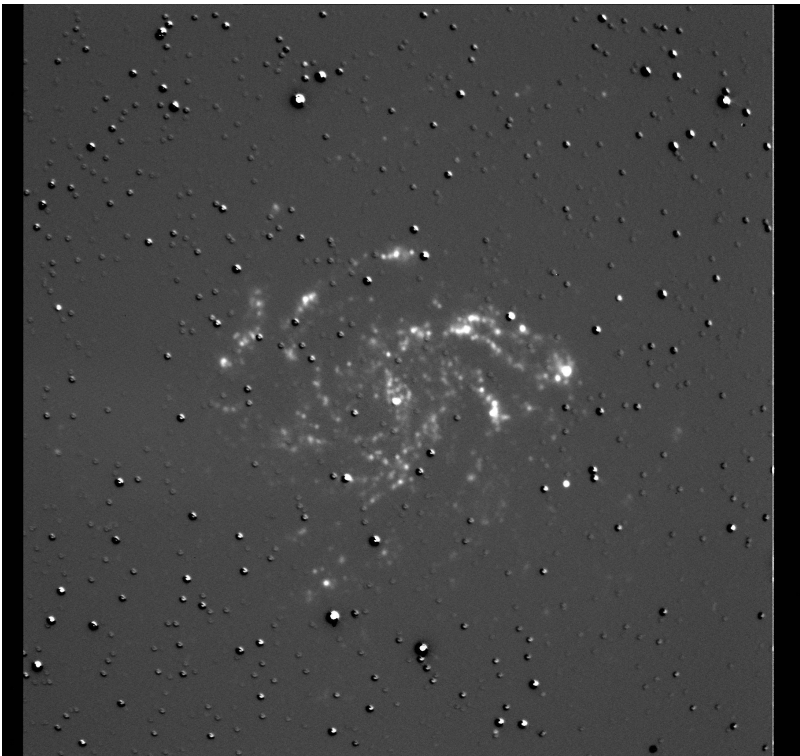
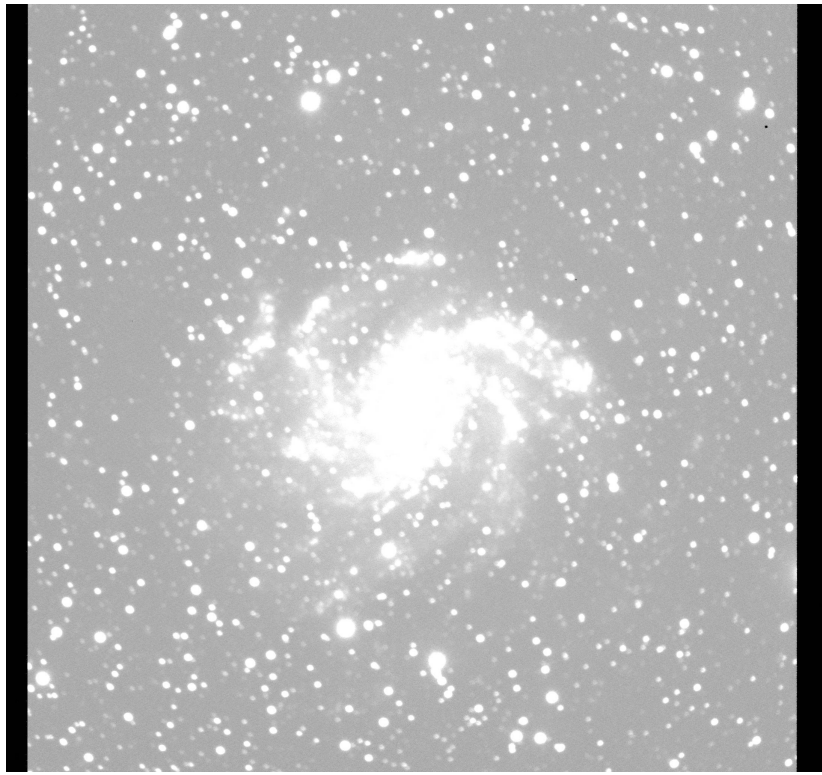
The following procedure is for MaxIm DL 4 and is not the only possible method of processing and reducing data.

1. Collect data or request data from an observatory on a CD-ROM. Data should include a minimum of 10 bias exposures, 6 sky flats with the H-Alpha filter and 6 from the R-Band, 3-5 images taken of the object in H-Alpha (6563 Å), and same number of images taken with R-Band filter.
2. Insert CD-ROM into computer that contains the program MaxIm DL 4
3. Click on MaxIm DL icon on desktop.
4. Open all H-Alpha images by clicking on file, scrolling to open, selecting Local C:, and selecting the appropriate drive that contains the CD-ROM data. Create a box around the icons of the H-Alpha images and click on open when they are all highlighted. The images will appear larger than the window provided so click on zoom minus icon twice to make them fit. Directly above the provided viewing window a bar will display each of your images. Make sure all of your H-Alpha images appear there. They will be stacked.
5. Click on Process, scroll to Set Calibration. The set Calibration window will appear. At the top will be some boxes that can be

- checked and unchecked. Check the following boxes: Calibrate Flats, Calibrate Bias, Bias Subtract Flat. The rest should be unchecked.
6. Underneath the top window there is an arrow that allows you to select Bias, Flat, Dark, or Auto. Click on the arrow and select Bias. Then click on Add Group that is under the top window. A Bias 1 group will appear in the top window.
  7. Click on the Add button to the right of the bottom window. The Open window will open and you may select each of the Bias icons. Make sure to highlight all of the Biases. There should be at least 10 of them. Click on open. In the bottom window all of your Bias data should appear.
  8. Click on the drop down box to the right of the bottom window and select median.
  9. Back to the top window, select from the drop down box that you previously selected Bias and select Flat. Click on Add Group. Another group will appear that says Flat 1.
  10. To the right of the bottom window click on Add. Make sure the Flat 1 is highlighted in the top window. Again the Open window will open. Select and highlight each of the H-Alpha Flat icons and click on open. The Flat data should now be displayed in the bottom window.
  11. Make sure that the drop down window next to the bottom window displays Median.
  12. Check the boxes in the top window next to Flat and Bias if they are not already checked.
  13. Click the OK button on the bottom.
  14. Make sure that all of the H-Alpha Images are in the viewing window.
  15. Select Process from the toolbar and scroll to Calibrate All. The process takes a few minutes and then a new image appears over the H-Alpha images. Save this file as H-Alphacomb.fit.
  16. Close all files in the viewing window by clicking on the x.
  17. Click on File in the toolbar and scroll to Open. The Open window will appear. Highlight all the R-Band images. Click the Open tab.
  18. The files will open in the viewing window. Make sure that all of the R-Band images are listed directly above the viewing window.
  19. Click on Process in the toolbar and scroll to Set Calibration. The Set Calibration window will appear. All of the same information that was there will still be there. Click on the drop down box under the top window and select Flat. Then click on Add Group. Flat 2 will appear. Make sure that Flat 2 is highlighted. Next to the bottom window click on Add. The Open window will appear. Highlight and select each of the R-Band sky flats. Click on the Open tab. The files will now be listed in the bottom window. Make sure that Median is selected next to the bottom window. Make sure that the same three boxes are checked on the top. Now make sure that the Bias 1 is checked and the Flat 2 is checked. Make sure that the Flat 1 is unchecked. Click on the OK tab.
  20. Click on Process in the toolbar and scroll to Calibrate All. Again this will take some time. A new window will come up. Save this file as Rbandcomb.fit.
  21. Close all windows by clicking on the x.
  22. Click on Open in the toolbar and scroll to Open. The Open window will appear. Select the H-Alphacomb.fit and the Rbandcomb.fit. Click the Open tab.
  23. Make sure that only the two images are in the viewing window.
  24. Select Analyze and scroll to Photometry. The Photometry window will appear. Click on the drop down box on the right side and select

new object. As you move the cursor onto the picture an annulus and an aperture will appear in blue. Right click to get a drop down window and select Set Aperture Radius and then scroll down and select 18.

25. Right click again to get the drop down window and scroll down to Set Gap Width and then select 0.
26. Right click again to get the drop down window and scroll down to Set Annulus Thickness and select 5.
27. Make sure in the Photometry window that all the boxes are checked.
28. Select a star that you would like to compare. Push shift and left click at the same time and move the mouse around. This is called stretching the image. Stretch the image until the picture appears white and washed out, but the stars are bigger and difficult to see. Now place the annulus over the star and make sure that the outer edge of the star does not touch the outside ring. Make sure the star is centered and double click to select the star.
29. There are two windows that are up at this point. One is the photometry window and the other is the information window. In the information window look for the number displayed next to the intensity. Write this number down. This is your sky subtracted intensity. This means that the pixels that surround the star are subtracted out.
30. Go back to the Photometry window and click on the image that is not selected. The same star will be selected and its data shown in the information window. Again look at the number next to the intensity. Write this number down.
31. Repeat this process for nine other stars.
32. For each set of numbers divide the Rband value by the H-Alpha value. The results should be similar. If they are not similar throw the outliers out and use the mode. This number is the scale number that you will scale Rband by to subtract out Rband from H-Alpha. The value arrived at should be greater than one. Divide one by this number and this will give a percent. Example:  $R_{band} = 1.09 \times 10^6$   $H\text{-Alpha} = 202,000$   $1.09 \times 10^6 / 202,000 = 5.3\dots\dots\dots$   $1/5.3 = 19 \%$ . 19 % is your scale factor for Rband. This means that you only want to use 19 % of the light received in Rband to subtract from H-Alpha.
33. Click on Process in the toolbar and scroll to Pixel Math. The Pixel Math window will appear.
34. Under Image A select H-Alphacomb.fit.
35. Under Image B select Rbandcomb.fit
36. Under Image B enter your scale factor in the scale factor % box.
37. Click OK. This is the final product. It should appear darker. Why?



***NGC 6946 Before Reduction (H-Alpha)***

*NGC 6946 After Reduction*

*Star forming regions appear as bright regions in the Reduced image. Notice most of the stars in our galaxy are now not visible. The stars that are still visible emit H-Alpha and are amongst the brightest of the stars in the image.*

***Questions:***

Why does the picture look different?

Why does part of the picture disappear?  
Why do the stars mostly disappear?  
Why is this helpful to know?

***Teaching Strategy: Conceptual Change (Constructivist Model)***

*Strengths:* The teaching model used for this lesson Conceptual Change. It is very effective for this type of lesson because it is capable of being introductory in nature, yet touch on many different topics that relate to goals. This strategy allows the teacher to tap into student knowledge and imagination. There will be many opportunities for one-on-one interaction, student tutelage, and group interactions. Students will be challenged to come up with meaningful explanations for the given problems. This is a hands on/minds on experience and students will get out of it what they put into it. The instruction portion is critical so spend time giving the students the necessary information and plenty of time for questions and deep explanations. Students will get to work with a computer program and build problem-solving skills. Students' disposition towards this activity should be good because it is new and exciting to see things that few people see and do things that few people do. It is a great culminating experience to studying the nature of light and the light spectrum.

*Weaknesses:* Students who are naturally shy or introverted could be left behind because they don't ask questions. Frequent follow up is critical to student success. Make sure each student is aware of what is happening and what is expected of them. Some students may not be able to process what is happening with the program so detailed explanations will be in order. The program can be complicated and requires a clear understanding and an ability to follow verbal and written instructions.

Created by Chad Sharpe, University of Wyoming Research Experience for Teachers Program, July, 2005