Ionization Zones in HII Regions

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Abstract

The HII region of S212 was analyzed in H alpha, OIII, SII, and V band filters. From the data a RGB image was created using Halpha, OIII, and SII. Due to the offset of WCS coordinates of OIII and the other two the image came out a bit blurry. Next the structure of HII region was looked at. For the most part all three filters showed a circular shape however H alpha displayed a bulge of activity near the center. The position of the H alpha bulge to the center of the OIII and SII region was found to be $D = 0.03142 \pm 0.004$ degrees.

Introduction

An HII region are areas of interstellar space where atomic hydrogen are ionized. These are gas clouds that surround stars and can range from 1 to 100 light years across. The temperature of these regions reach up to about 10000 kelvins. HII region emits a variety of emission lines some example are those in the balmer series. Although these regions are mainly composed of hydrogen there are also other elements mixed in there such as oxygen, silicon, or nitrogen. In this experiment focus on emission lines of H alpha, OIII, and SII and also the V band. The theory behind these lines are as follows as the electron orbits the atom it can be energized to a higher state by a specific photon frequency. The frequency of the photon depends on the energy gap between the two energy levels. Once the electron is at a higher state it would eventually decay back to a more stable state and thus releases a photon with energy equal to the difference of energy level. We can detect these specific photon energy as H alpha or OIII lines which gives us an insight on what the cloud is made up of. To find emission lines we used the observatory located on top of the Physics building of The University of Waterloo. The Observatory consist a 14" Celestron Telescope with 3.91m focal length. (Fich 2016)

Observational Method

The observatory is located at longitude: -80.541^o and latitude: 43.4706 North with elevation: 340m (Fich 2016). The target for the lab was HII region S212 which can be located near the open cluster NGC 1624. The logic behind picking S212 is that the object is high enough in the sky during the winter so there shouldn't be problem locating it. Also the symmetric nature of the object will give us a talking point to compare the results to .On the night of observation the skies were clear and temperature outside was -14^o Celsius. Using theSkyX program on the telescope we were able to locate S212 under the name SAC sh2-21 as a result a skychart was not needed. Once the object was located we began to take images with 2x2 binning. We decided to use 2x2 binning instead of 1x1 is because we wanted the image to have a sharper focus and also less noise. Ideally 3x3 would be better however the group before us was doing the exact same object so the TA decided that changing the binning was necessary so we weren't doing the exact same lab as the previous group. We proceeded to take H alpha (656.46nm), OIII(436.44nm), SII(407.23nm), and V band in that order. For each filter we took three different exposure times: 200s, 30s, and 1s. With the 200s we noticed that the stars started to drift on the image however it was advised at the time by the TA to do 200s so we could get enough data. However upon analyzing the data 100s exposure would be sufficient.

Analysis

Part A

To create the RGB picture the program AstroImagej was used. The process was as follows: first load the three filters Halpha, OIII, and SII into the program. The 200s exposure time was used since the 30s weren't long enough to get a clear image. Then a stack of three images was created. From there I created a composite color image under the color tab. This is where I was able to adjust the contrast for each image. The H alpha is colored in red, OIII in green and SII in blue. Lastly once all the brightness and contrast is done the imaged is smoothed so there is less pixelation on the image. Finally the result can be seen below:

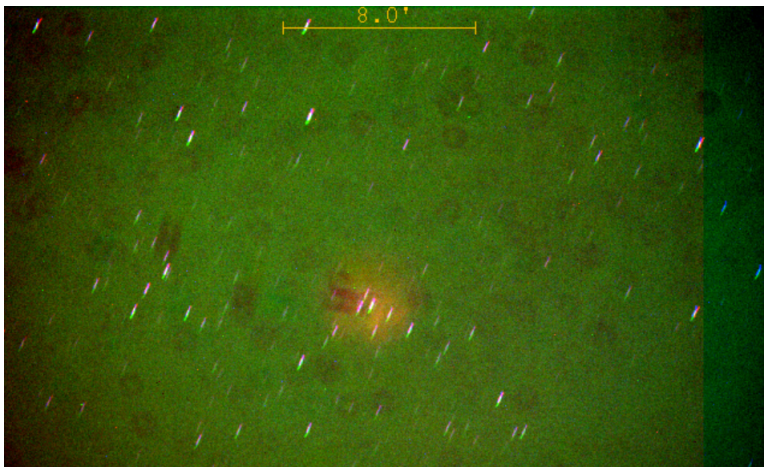

Figure 1: RGB Image of H alpha (red), OIII (green), and SII (blue)

Unfortunately there is a bit offset between green and the other two images. Within the program nothing much can be done since the offset is the result of WCS coordinates been off. The coordinates were obtained from astronomy.net so there isn't too much that can be done to align the green image. The offset of the right ascension is about 0.561s and 10 arcsec for the declination.

Next a discussion would be made about using the V band in an RGB image. Using the 200s exposure the RGB image below consists of H alpha (red), OIII (green), and V band (blue):

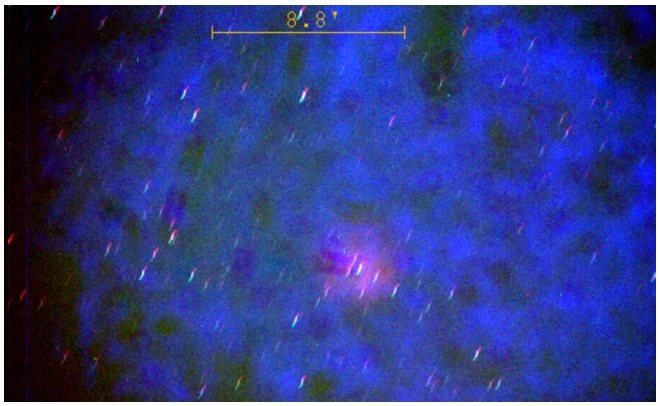

Figure 2: RGB Image of H alpha (red), OIII (green), and V band (blue)

Again there is offset in the wcs coordinates between OIII and H alpha like in the previous image. We see that the V band captures S212 as an almost circular region. This image can be compared to the image taken by the Digital Sky survey (Arora Waterloo):

Figure 3: V band Image of SH212 From Digital Sky Survey

Compared to the image of the digital sky survey we can see the spherical structure of the HII region. The blue is quite strong in the RGB image this is due to the fact that the V band ranges from about 500nm to 700nm as a result it picks up both the OIII and H alpha

lines. So areas where H alpha and OIII is strong the V band would also be bright.

Part B

The main purpose of this analysis is to first understand the underlying structure of the H alpha, OIII, and SII in S212. Second to determine the ratio of the emission lines along various directions. The method used would be as follows: the image below is the RGB function used in DS9. Where the H alpha is the red, OIII is the green, and SII is blue.

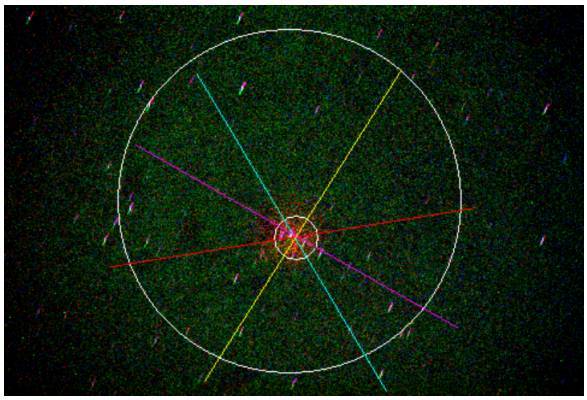

Figure 4: DS9 RGB Image of H alpha (red), OIII (green), and SII (blue) with Circular and line regions

There are two key things in the image one is the two circles and the other is the four lines with equal length. The circles would be used to find the offset in position of the structures. Their center were determined by approximating where the middle of the structure is in the image. By inspection it seems the OII spans across a the whole image but H alpha line is concentrated in a smaller circle near the middle of the image. Later on the analysis would give a more indepth insight on the shape of H alpha. Next the lines are mainly used to determine the ratio of emission between the three filters. In DS9 the "Plot 2D" of the analysis tab for the line gives a number of count along the length of the line. This function would give a sense of emission proportion between the three filters.

The ratio of emission between the three filters would be looked at first. Below are four graphs representing the four different line seen in the image: yellow, cyan, purple, and red. The red graph is the H alpha brightness and the green and blue is the OII and SII respectively. From the four graph we get a very consistent trend of OIII having the highest count with H alpha and SII trailing in that order. Over the four different lines the three filters are consistent this suggest that the three filters covers a circular region. However H alpha peaks near the center of the lines which is what is expected from looking at the image. We see there is a bulge of H alpha emission in the small white circle which is reflected in the four graphs. Another key feature is that near the center of the lines there are spikes of all three filters. This is mostly due to the fact the lines intersect that stars and thus detects a

spike of H alpha, OIII, and SII lines. This is apparent in the purple line (bottom left figure) where it intersects 3 stars and as a result there are spikes in all three filters.

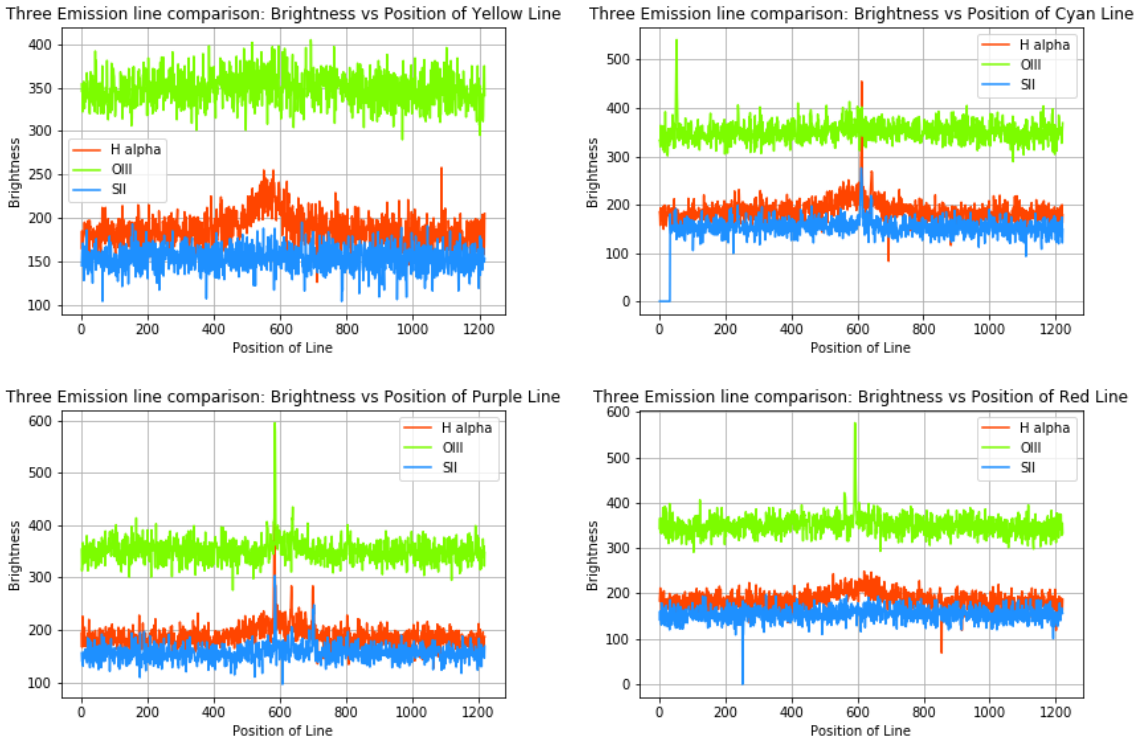

Figure 5: Emission line comparison of H alpha, OIII, and SII filters

From the graph the counts of OIII is centered around 350, H alpha not including the bulge is around 180, and SII is 150. This gives a sense of ratio between the three filters.

In the next page each pair of graphs of figure (6) represents the four lines, however this tim, it's split by the different filters: H alpha, OIII, and SII in that order. The plots on the left are the same as the right but one is just scatter plot while the other is a line. For each filter graph the color of the line/points represents the brightness count for each line in the image. For example in the first pair of graphs the four different color point represent one of the color lines in the H alpha filter. The purpose of these plots is to give a sense of the shape of each region. Since the lines are in various direction if the shape is circular the shape would be a consistent line across the plot while for ellipse for example the direction of the major axis line will have counts stretched across the line while on the minor axis the line would have a dip on the edges since it isn't picking any counts. Agreeing with the previous graphs we see that there is a bulge in the H alpha graphs. This suggest a circular concentration in the center of the line. It's circular because the bulge is symmetric over it's center. On the other two figures the OIII and SII shows a circular shape since the counts along the lines are consistently centered around 300-400 in OIII and 125-200 in SII. With the general shape of the filters determined to be circular this was the main reason for the two white circles in DS9 image. The large white circle encompasses OIII and SII region while the smaller circle focuses on the bulge of the H alpha. The large circle is centered at $RA = 4:40:34.9341 \pm 6s$ and $Dec = +50:27:46.880 \pm 2arcmin$ the error were measured approximately how much the circle can be moved and still encompass the area. Next for the small circle $RA = 4:40:39.7902 \pm 2s$ and $Dec = +50:25:53.814 \pm 15arcsec$. To find the angular distance between the two circles this equation would be used (Bruun 2010):

$$cos(D) = sin(dec1)sin(dec2) + cos(dec1)cos(dec2)cos(ra2 - ra1) \tag{1}$$

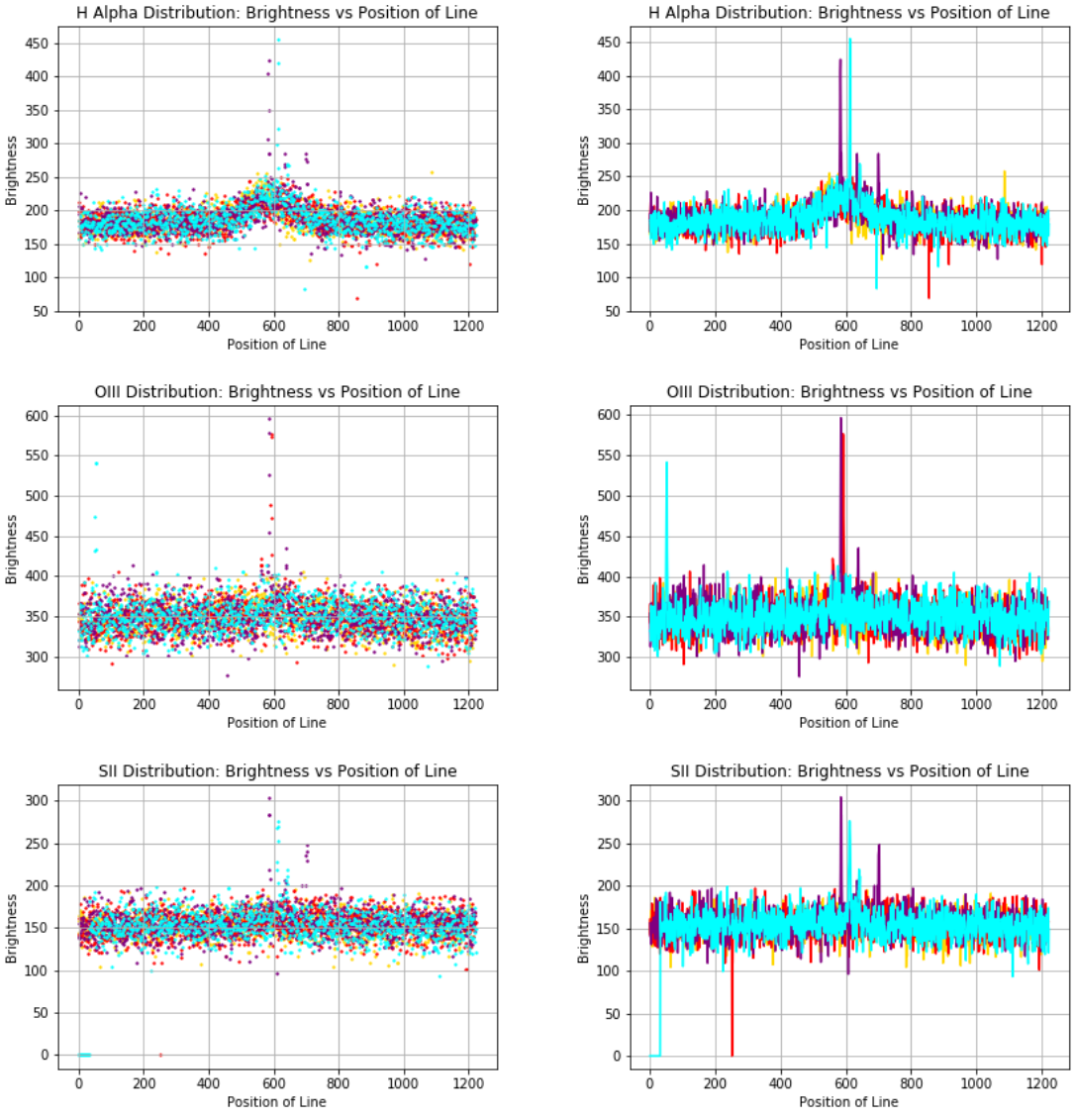

Figure 6: Distribution of brightness along the four lines of H alpha, OIII, and SII.

Plugging these two values in gives that the distance D in degrees is $D = 0.03142 \pm 0.004 = 113.1 \pm 15 arcsec$. The error was found by taking the upper and lower limit of the uncertainty and plugging the upper and lower bound into equation (1). For finding the upper bound the uncertainty would be added to the right ascension and declination of the large and small circle. Likewise the lower bound would be subtracting the uncertainty. As a result we found that the main bulge of H alpha is aligned about 0.03142 degrees from the center of the OIII and SIII circle. One possible reason for this bulge is due to the fact that the region is located where there are multiple stars. Since H alpha lines emitted by nebula's, it's not surprising that near a region with many hot stars there would be an increase in H alpha line emissions.

Conclusion

To conclude the purpose of observing S212 is to first create a RGB image using H alpha, OIII, and SI filters; second to understand the structure and ratio of emission of the three lines. From the images we were able to create an RGB image using the AstroImageJ program. However due to the offset of the WCS coordinates the OIII image is misaligned by about 0.561s in the RA and 10 arcsec in the DEC. Next to analyze the structure of the HII region we created multiple lines spanning across the region in different directions and in DS9 found the brightness/count versus the length of the line. From this we were able to determine that the all three emission lines have circular structures however the H alpha showed a bulge near the center. From these graphs we were also able to determine the offset position of the center of SII and OIII versus the bulge of H alpha. This was found to be a distance of $D = 0.03142 \pm 0.004$ degrees.

References

(Bruun 2010) Bruun SG. 2010. How to Calculate the Angular Distance Between Two Stars.Online. Available from: http://www.gyes.eu/calculator/calculator_page1.htm

(Fich 2016) Fich, Mike.2016. Observing Manual. Phys 370L. Waterloo (On): University of Waterloo.

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