ASTRONOMY

THE SECRET PATTERN OF THE UNIVERSE ---

THE NORMAL DISTRIBUTION

{AIM}

TO INVESTIGATE THE RELATIONSHIP BETWEEN BRIGHTNESS OF STARS AND THE NUMBER OF STARS OF THAT BRIGHTNESS.

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MEMBERS:

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3. KUA LI MING

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1. Acknowledgement

Good day, our dear reader, welcome to our astronomy project.
In this project, we would show you the beauty of the equatorial stars.
Due to our immense keenness towards astronomy, we purposely captured every single light of the firmament and dedicatedly include them in our astronomy project. All photos inside are produced by our own.

Even though this experiment had been conducted by many scientists long time ago, we insist on selecting this experiment as our project since it could inspire us to relate science with mathematics and wonder about the behaviour of the Universe.

All of these images are taken without using tracker. We hope that you would enjoy!
Last but not least, we would like to convey our appreciations to our dear reader for spending their precious time to have a glance on our project. Thank you. ☺

1a. Words of appreciation

We would like to mention the names of the following organisations, software, website for aiding us in producing the project successfully:

Organisations:

- E.A.A.E (European Association for Astronomy Education)
- E.S.O (European Southern Observatory)

Teacher (leader) :

- Mr Yeo Chong Eu (Chemistry teacher)

Software, tools and websites :

- I.R.I.S (Interface Region Imaging Spectrograph)
- Regim
- Nikon DSLR camera
- The AccuWeather (satellite weather)
- Astrosurf
- Wikipedia
- Google Earth

Environment :

- The Universe
- The good weather condition

Leader’s profile:

He is a dedicated teacher who is willing to spend his time with us in order to guide us to do our project successfully. Even though astronomy is not his preference of teaching subjects, his commitment in assisting us would not be forgotten.

He feels surprise when we ask him for becoming our leader. As we know, in Teluk Intan, a small rural place in Malaysia, it is hard to find such interesting event to carry out! He agrees with our notions of doing the interesting stellar project.

2. THE ABSTRACT

In the past, a great Mathematician or astronomer, Johann Carl Friedrich Gauss invented the 'Normal Distribution' curve after he noticed that his astronomical data, especially star brightness exhibits the bell-shaped curve. After some time, he decided to use this mysterious pattern to predict the nature's behaviour.

We are amazed by the distribution pattern, hence, in order to have a deep insight on the normal distribution and to encourage us to apply this 'law of mathematics and nature' in our daily lives, we decided to carry out this 'research'. Nothing is as amazing as mathematics and the universe, in fact, we could notice that almost every event happening around us, if it is recorded in term of mathematics, we would not be surprise that 'Sombrero Hat' shaped graph would emerge as we had expected. Then, we started to question ourselves : " Is there anything that do not obey that curve?"

In spite of that incomprehensible pattern, meanwhile we are trying to find something that does not obey the 'Normal Distribution' pattern. Night time stars are very alluring and mind blowing, as there are so many of them. Hence, this project is indeed a good start for us to unveil the mystery of the Universe!

3. General Knowledge on Astronomy Related to our Survey

The Measurement Unit for Brightness of Stars → Magnitude

- The apparent magnitude ← *(this is our main concern)*
- The absolute magnitude

Magnitude is the logarithmic measure of the brightness of an object. It is usually measured in wavelength of optical or near-infrared. The magnitude system dates back roughly 2000 years to Greek astronomer, Hipparchus. He classified stars by their apparent brightness, which he saw as "the bigness of stars". This is because brighter stars appear more "larger" than dimmer stars.

In 1856, Norman R. Pogson of Oxford proposed that a standard ratio of $\sqrt[5]{100} \approx 2.512$ be adopted in magnitudes, hence 5 magnitude steps corresponded precisely to a factor of 100 in brightness of stars.

The Apparent Magnitude

It is the direct view of the brightness of stars. Apparent magnitude of a star is a measure of its brightness as seen by an observer on Earth. Typically, the visible spectrum (Vmag) isused as a base for the apparent magnitude.

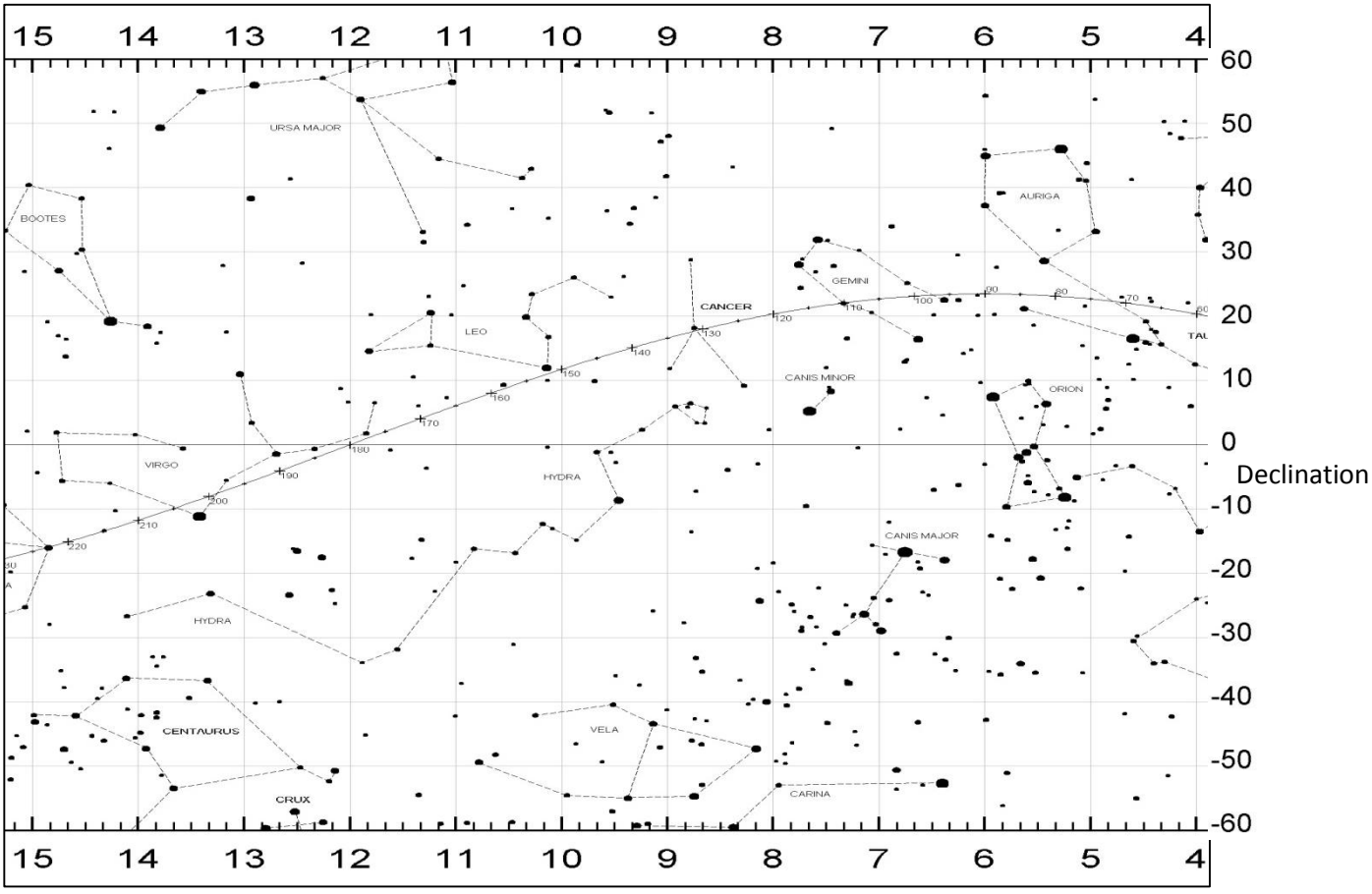
$$m_x - m_{x,0} = -2.5 \log_{10} \left(\frac{F_x}{F_{x,0}} \right)$$

"Where "m" is the magnitude of star, "F" is the flux (simply known as brightness), "x" is the star being studies, "x,0" is the reference star."

We will show the calculation later using measurement from software, IRIS.

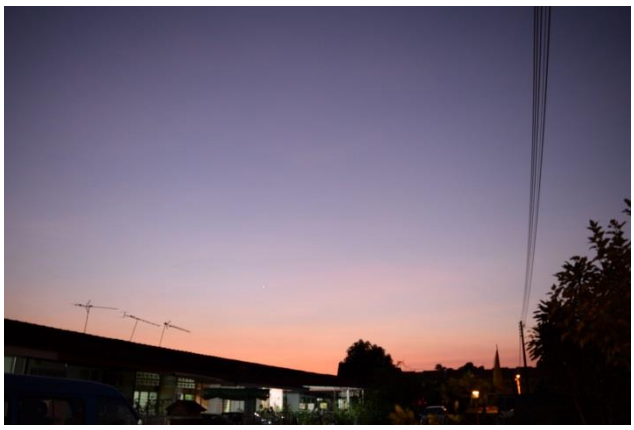
4. Observation and Problem Statement

Since our time of carrying out this observation is during December 2014 to May 2015, hence, the best view of the available night sky is from the winter constellations, namely starting from the Orion until the summer constellations, the Centaurus.



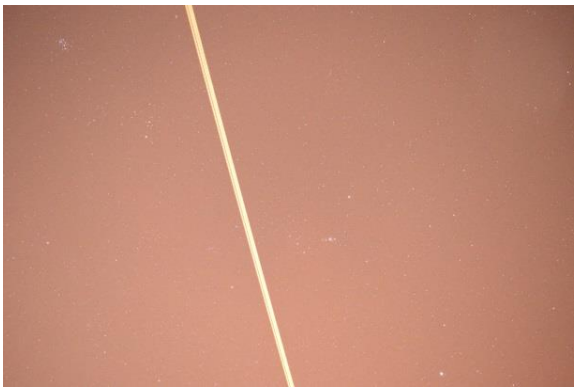
Almost half of the region of the equatorial sky used for survey = (Surveyed Area / Total Area)*100% = [((15-4)*(120)) / (24*120)] * 100% = 45.83 % (2 decimal places)

This is our obvervation site → our frontyard



The camera setting could be crucial for determining the image quality. As our prime foul is the light pollution, we had to compromise on the two features of camera, these are exposure time and ISO setting. By taking several photos of the stars, we could compare on which is the best camera setting for our observation site :

ISO 800 , 15s exposure time , f/ 3.5



ISO 6400 , 15s exposure time , f/3.5

We notice that when we capture the image which is near to the horizon, it appears very bright, this is caused by street light even though our location is situated away from urban area.

Hence, we decide to use the following camera setting for our observation:

- ISO 800
- Exposure time : 15s
- Focal ratio, f/ 3.5

This is the compromised camera setting for our project, as it could minimise the light pollution besides reducing the noise of photo.

5. Observation & Hypothesis

After stellar photo acquiring process at the front-yard, we examine the photos. We notice that there are different brightness of stars and we want to investigate whether the brightness of star and their numbers satisfy the Normal Distribution when the data is plotted on a graph.

Combination of 2 photos, each single shot of 15 s exposure time, iso 800, f/ 3.5 each, Left & Right.
**This photo is not used for photometry.*

According to the photos that we have taken, our … …

Observation :

Most stars seem to have the same brightness whereas there are a little portion of the stars which are either very bright or very dim.

Hypothesis :

The graph of the number of stars against the brightness of stars exhibit Normal Distribution.

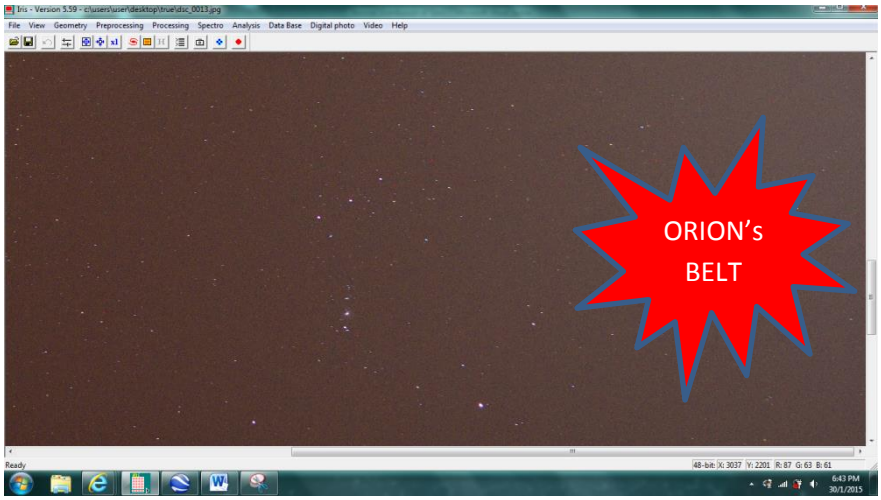
6. Precaution

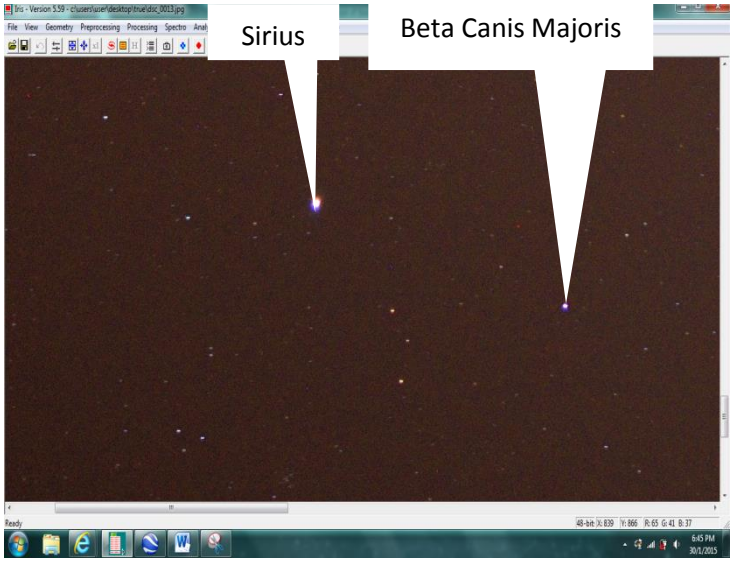
- In order to obtain fair result, we do not apply any changes on the photo for star brightness analysis.
- Since the ISO setting of camera is considerably low, hence the photo taken would not be too noisy for photometry using the software, IRIS.
- There are some star number calculator software available, but we find that they include hot pixels, light pollution as stars, e.g : Regim software, even though the software could count the number of stars, but we could not convert the data into text for the use in Microsoft Word.
- Since we count the stars manually, this could be an advantage for us as we could differentiate between hot-pixels, dead-pixels in the photos and do not account them as stars.

However, our measurements will surely have random errors due to human-mistakes, hence, the amount of stars for survey should be as many as possible to reduce the error.

Star Data Collection Procedure:

1. Firstly, we engage the IRIS software to view our selected photo of the stars.

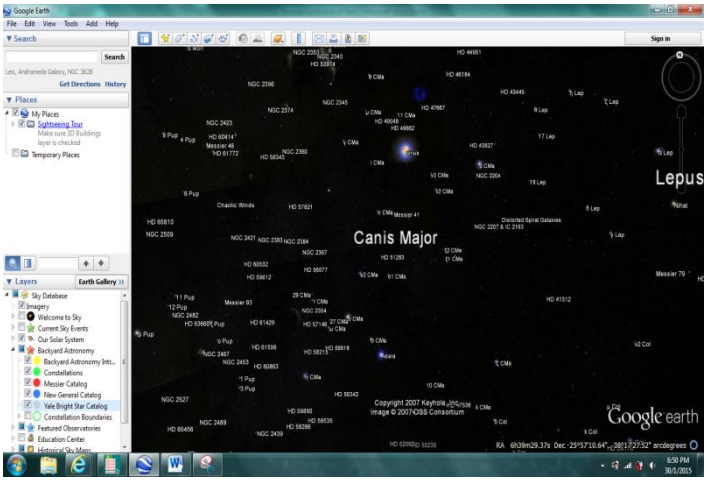




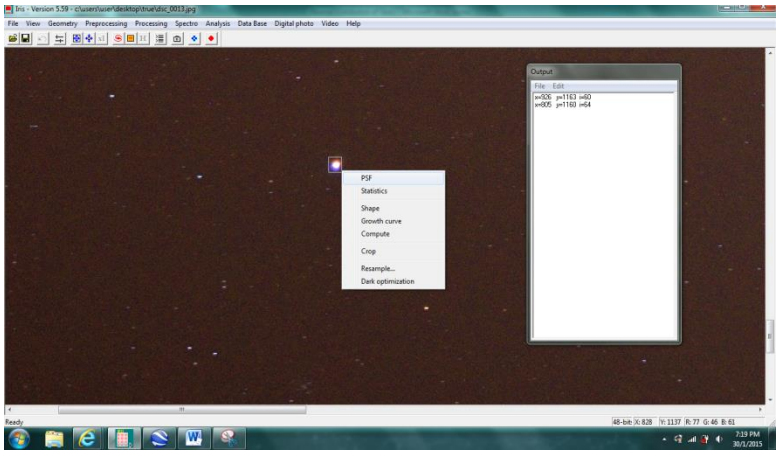
2. Then, we select one bright star in the photo to be used as the standard star for magnitude comparison. Remember to use 1x zoom recognised by IRIS to ensure fair photometry result. We choose non-variable stars as our standard star for photometry, e.g : The Sirius.

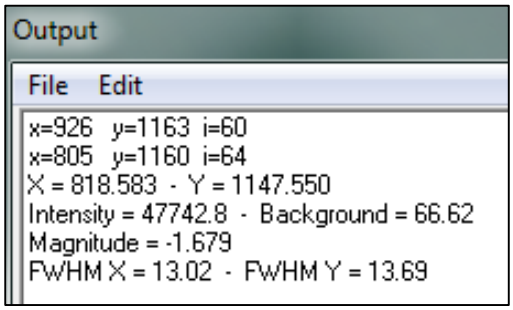
3. We check for the correct apparent magnitude of the bright star using Google Earth software.

4. Then, we locate that star in the Google Earth to check for its apparent magnitude.



5. Now, back to IRIS, we drag a box around the bright star, then right click the box and click on the “PSF” to check for the default magnitude of that star computed by IRIS.

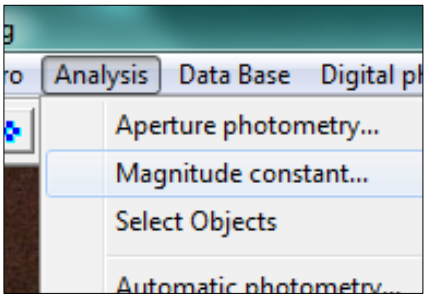


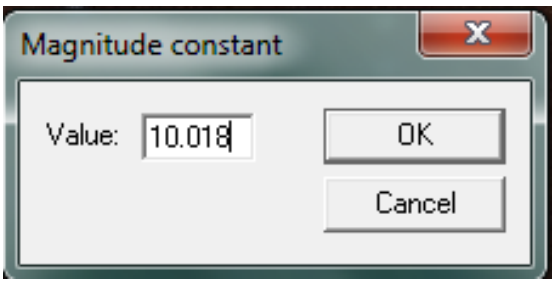


Where :
“Intensity” → star brightness calculated in Analogue Digital Unit. (ADU)
“Magnitude” → apparent magnitude

6. For example, the actual apparent magnitude of brightest star in the night sky viewed from our Earth is Sirius, the Dog Star is -1.47.

   However, its stellar magnitude shown by IRIS does not equal to the above value, hence, we should click on the “analysis” button, and press the “magnitude constant…” to adjust the magnitude of that star.





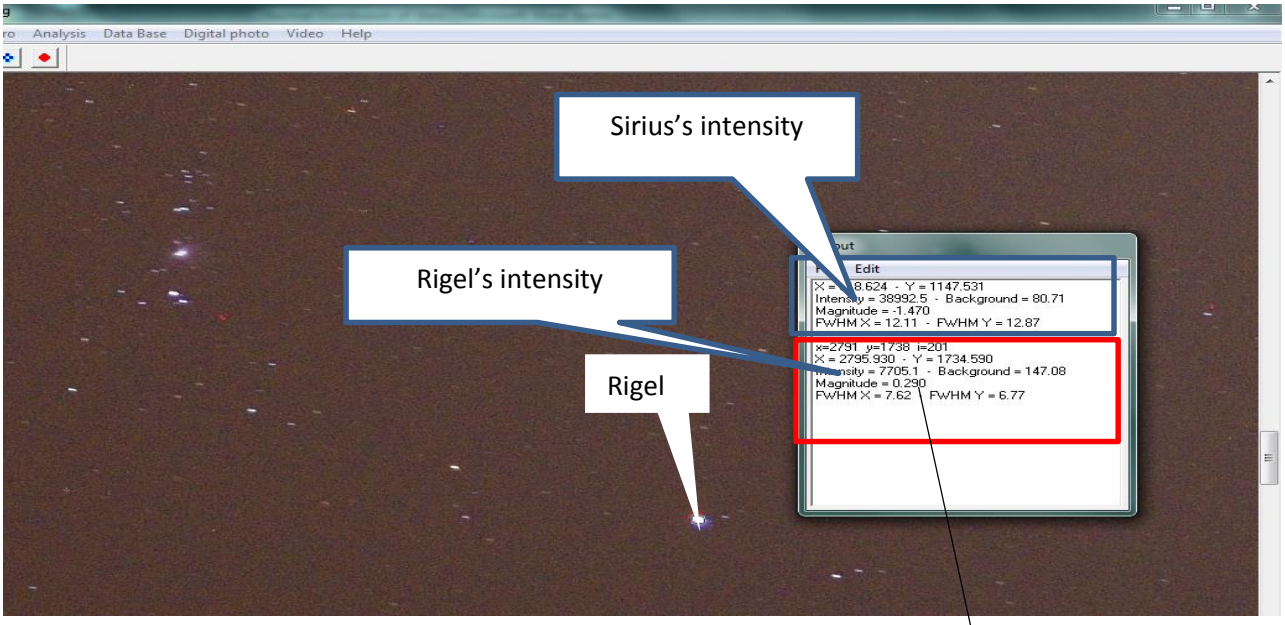
7. After some strives, we find that the magnitude of stars in our photo varies “linearly”. That means, the magnitude of stars in the photo are calculated by comparing the brightness of standard star with the selected one, whereby the stellar magnitude just varies by addition or subtraction.

   The function of apparent magnitude of stars in IRIS software :

“ Computed magnitude of star by IRIS + constant (number) = Apparent Magnitude of Star ”

8. This is because in the software, the star brightness is evaluated in logarithmic scale, hence, the apparent magnitude varies like a straight line.
9. In order to prove the above statement, we could do apply the “previous formula” to confirm the apparent magnitude of stars evaluated by IRIS.

$$m_x - m_{x,0} = -2.5 \log_{10} \left(\frac{F_x}{F_{x,0}} \right)$$



m_x = -2.5*log(7705.1/38992.5) + (-1.470)

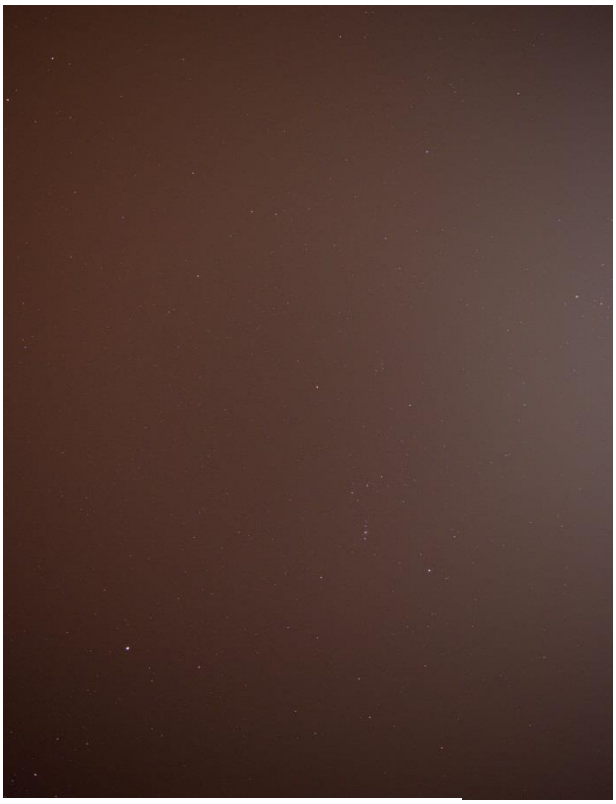
m_x = 0.290507003 (9 d.p) ≈ 0.290

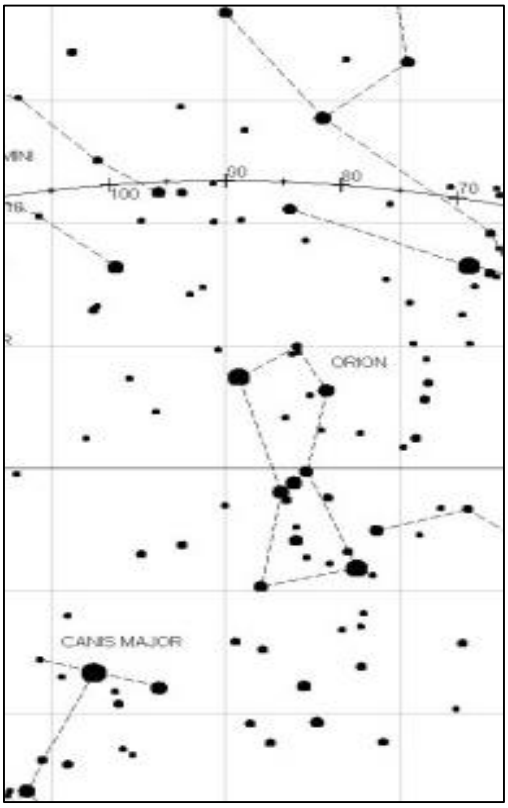
(PROVEN, the value calculated by IRIS matches our manual calculation.)

7. Counting Stars of Different Densities at Different Region of the Night Sky

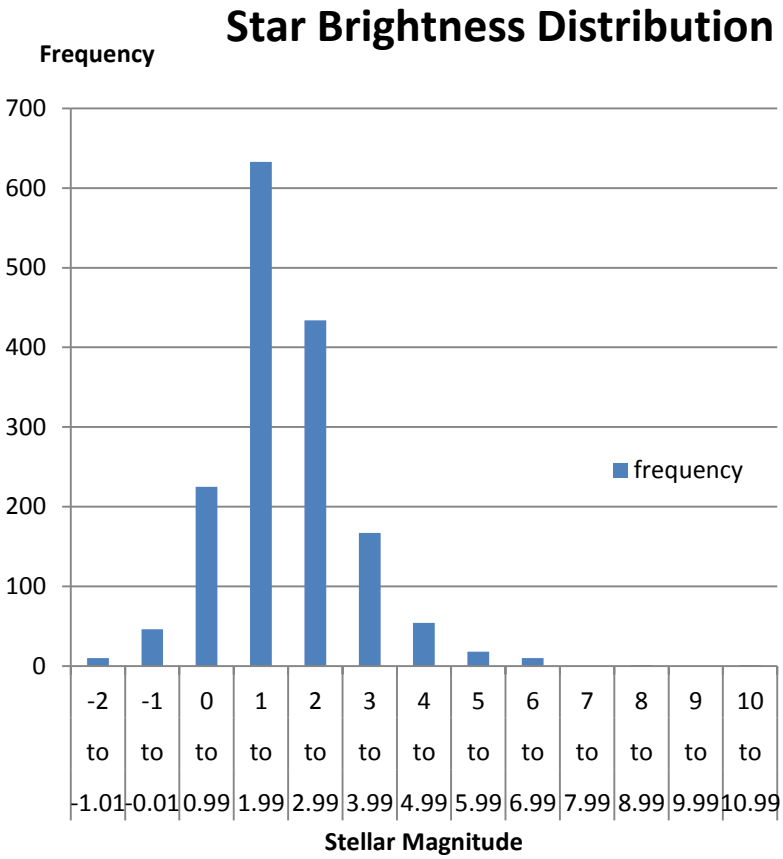
Hereby, below is the result of our data :

First Region of the Sky

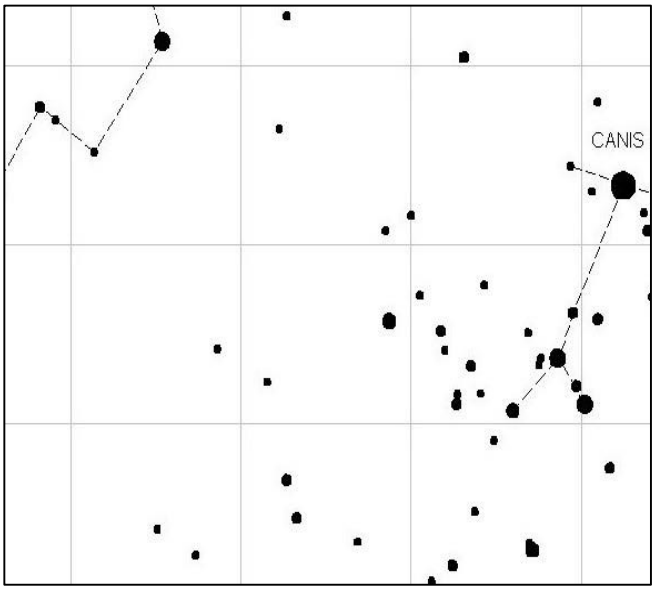




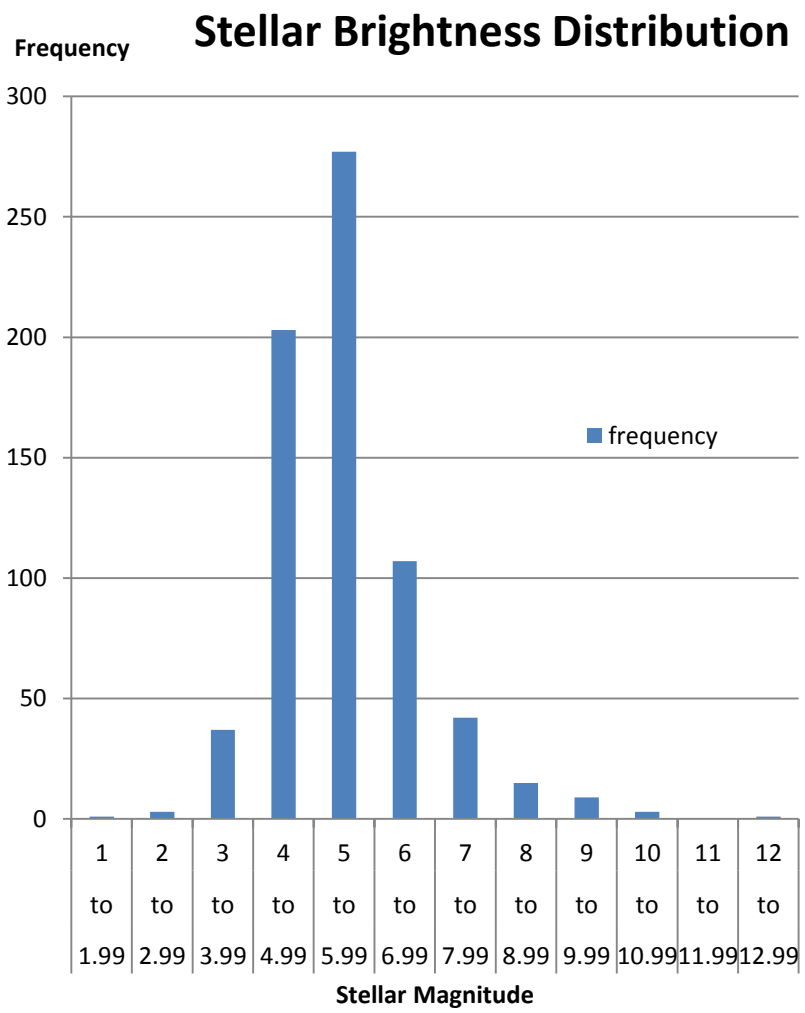
Stellar Magnitude			frequency
-1.01	to	-2	1
-0.01	to	-1	10
0.99	to	0	46
1.99	to	1	225
2.99	to	2	633
3.99	to	3	434
4.99	to	4	167
5.99	to	5	54
6.99	to	6	18
7.99	to	7	10
8.99	to	8	0
9.99	to	9	1
10.99	to	10	0
11.99	to	11	1
12.99	to	12	0
		Total	1600



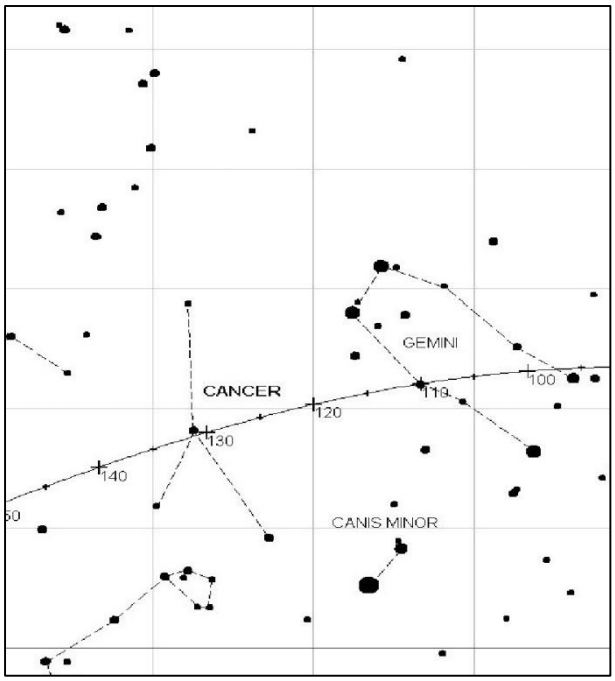
Second Region of the Sky



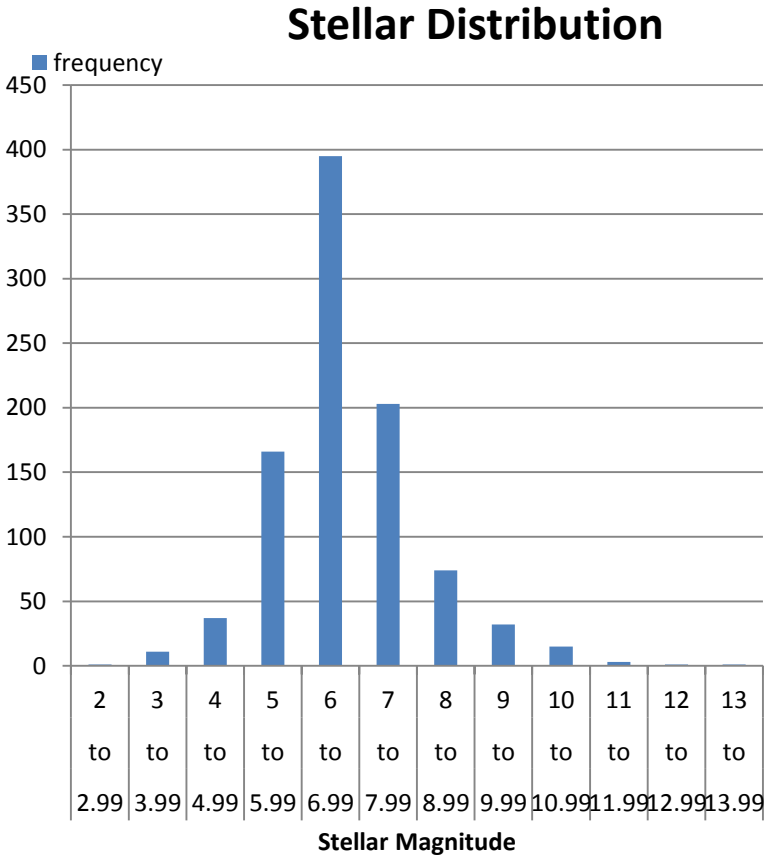
Stellar Magnitude			frequency
-1.01	to	-2	0
-0.01	to	-1	0
0.99	to	0	0
1.99	to	1	1
2.99	to	2	3
3.99	to	3	37
4.99	to	4	203
5.99	to	5	277
6.99	to	6	107
7.99	to	7	42
8.99	to	8	15
9.99	to	9	9
10.99	to	10	3
11.99	to	11	0
12.99	to	12	1
		Total	698



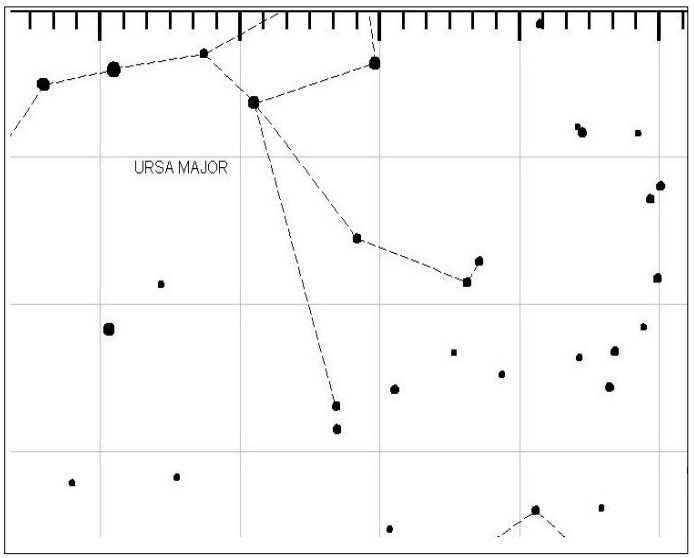
Third Region of the Sky



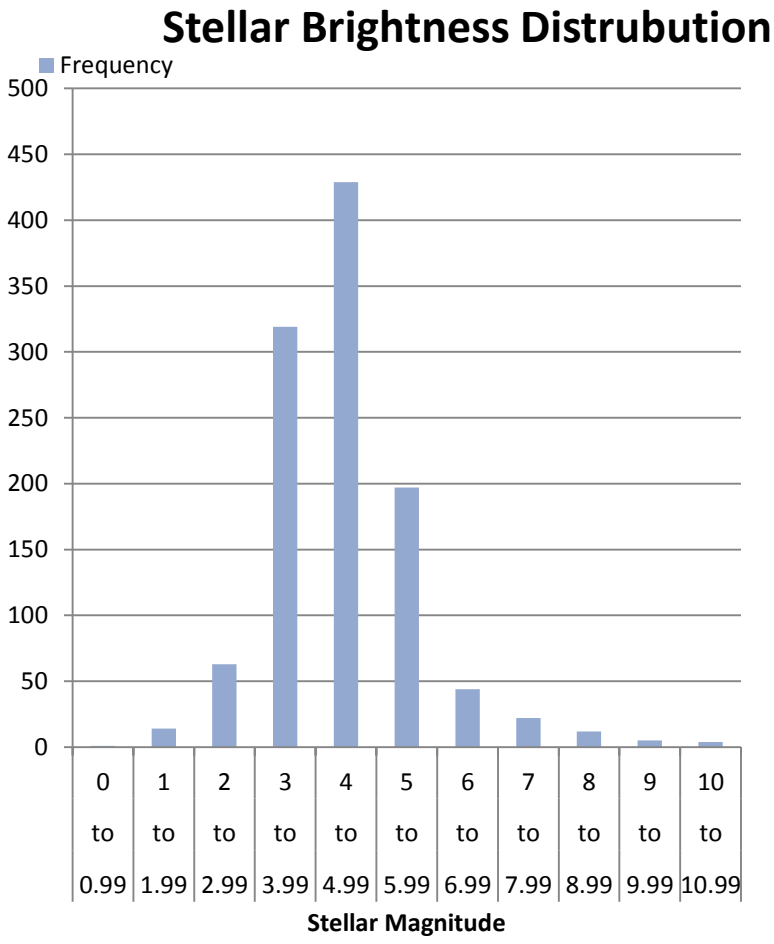
Stellar Magnitude			frequency
2.99	to	2	1
3.99	to	3	11
4.99	to	4	37
5.99	to	5	166
6.99	to	6	395
7.99	to	7	203
8.99	to	8	74
9.99	to	9	32
10.99	to	10	15
11.99	to	11	3
12.99	to	12	1
13.99	to	13	1
		Total	939



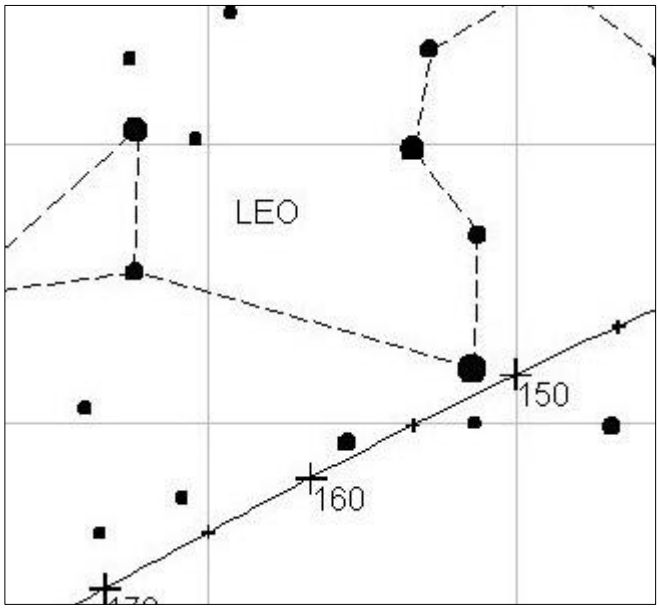
Forth Region of the Sky



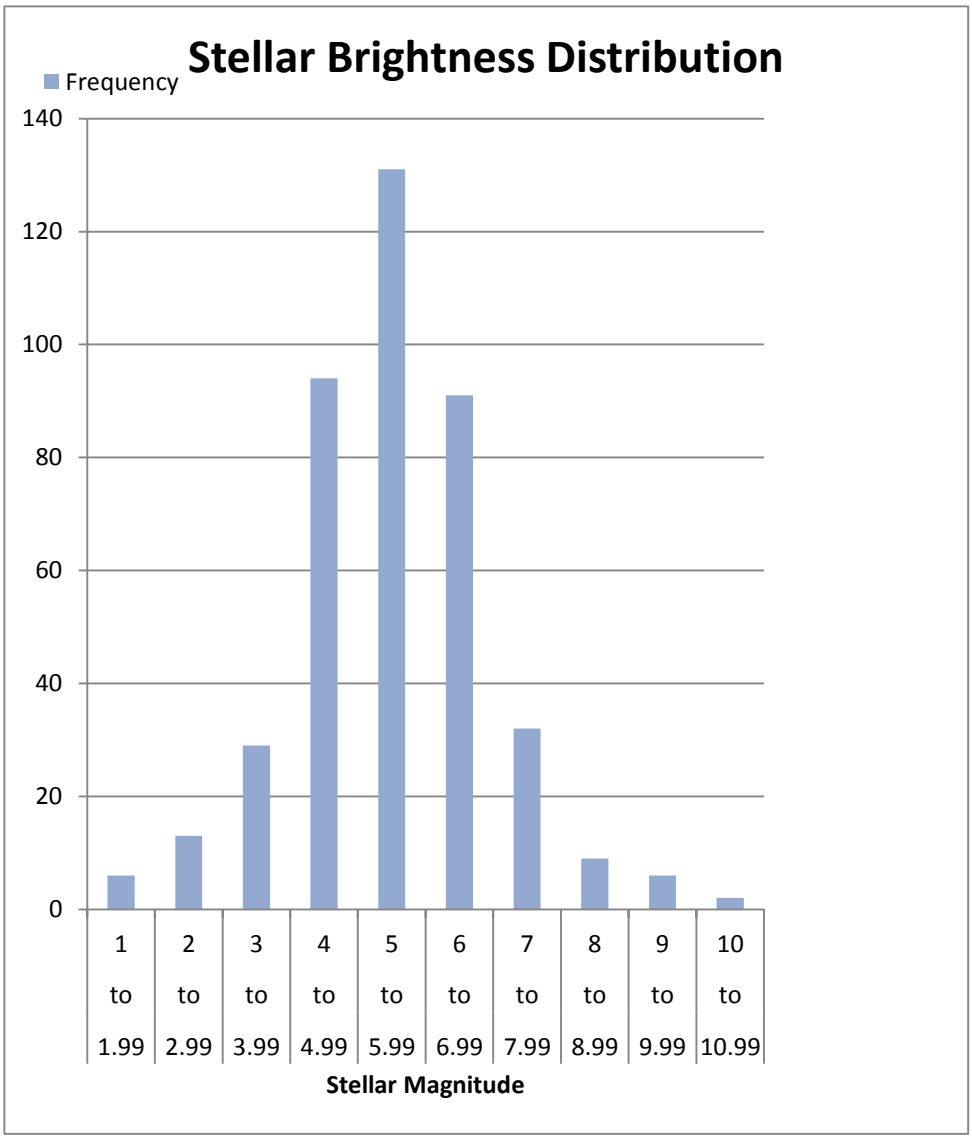
Stellar Magnitude			frequency
0.99	to	0	1
1.99	to	1	14
2.99	to	2	63
3.99	to	3	319
4.99	to	4	429
5.99	to	5	197
6.99	to	6	44
7.99	to	7	22
8.99	to	8	12
9.99	to	9	5
10.99	to	10	4
		Total	1110



Fifth Region of the Sky

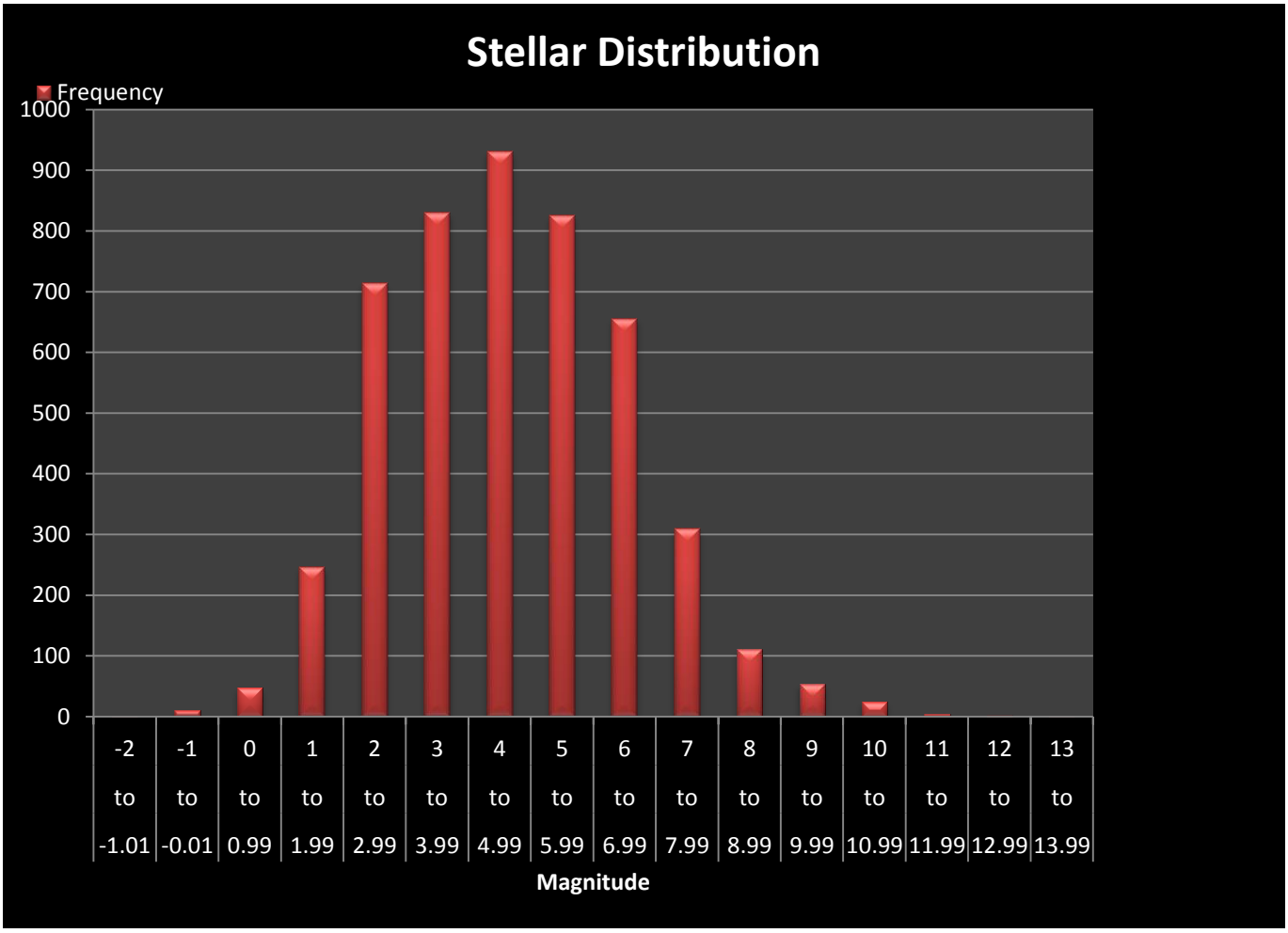


Stellar Magnitude			frequency
1.99	to	1	6
2.99	to	2	13
3.99	to	3	29
4.99	to	4	94
5.99	to	5	131
6.99	to	6	91
7.99	to	7	32
8.99	to	8	9
9.99	to	9	6
10.99	to	10	2
		Total	413



8. Verifying the Hypothesis

Combined Data of the Star



Stellar Magnitude			Midpoint	fx	f*x^2	Frequency / f
-1.01	to	-2	-1.505	-1.505	2.265025	1
-0.01	to	-1	-0.505	-5.05	2.55025	10
0.99	to	0	0.495	23.265	11.51618	47
1.99	to	1	1.495	367.77	549.8162	246
2.99	to	2	2.495	1778.935	4438.443	713
3.99	to	3	3.495	2900.85	10138.47	830
4.99	to	4	4.495	4180.35	18790.67	930
5.99	to	5	5.495	4533.375	24910.9	825
6.99	to	6	6.495	4254.225	27631.19	655
7.99	to	7	7.495	2315.955	17358.08	309
8.99	to	8	8.495	934.45	7938.153	110
9.99	to	9	9.495	503.235	4778.216	53
10.99	to	10	10.495	251.88	2643.481	24
11.99	to	11	11.495	45.98	528.5401	4
12.99	to	12	12.495	24.99	312.2501	2
13.99	to	13	13.495	13.495	182.115	1
		Total		22122.2	120216.7	4760

Analysis :

The Average Magnitude = (∑fx) / (∑f)
= 22122.2 / 4760
= 4.647521
= 4.6475 (4 d. p)

The Variance = [(∑f*x^2) / (∑f)] – [(∑fx) / (∑f)] ^ 2
= [(120216.7) / (4760)] – [(22122.2) / (4760)] ^ 2
= 3.656149
= 3.6561 (4 d.p)

The Standard Deviation = sqrt ("The Variance")
= sqrt (3.656149)
= 1.912106
= 1.9121 (4 d.p)

Conclusion :

From the experimental data above, we can conclude that the magnitude of stars do follow the "normal distribution", with mean magnitude of 4.6475 .

The standard deviation of the data is 1.9121, which denotes the spreading of the data is considerable big.

We had learnt that our experiments do have some errors due to the environment, and human-made error (random error), which could be reduced by acquiring data repeatedly and processing data carefully.

The total duration of this experiment is about a month.

Bibliography :

1. http://en.wikipedia.org/wiki/Magnitude_(astronomy)
2. http://www.astrosurf.com/buil/us/iris/iris.htm