The real and the apparent positions of the stars in Orion—a physics exploration using an online database

"The earth, that is sufficient,
I do not want the constellations any nearer,
I know they are very well where they are."

These are a few lines from the poem "Song of the Open Road" found in Walt Whitman's 1891 book "The Leafs of Grass."

And so I ask: ***Yes, the constellations are where they are, but where are they?***

Left: **The Constellation Orion**

Image Source:
http://functionalceramics.com/constellations/orion-constellation.html

§ 1: THE RESEARCH QUESTION

I feel magic in the stars, in the universe, when pondering the night sky. The recognizable patterns of the constellations feed my imagination with wonder. I was fortunate to study the astrophysics option in physics class and, when told to research an IA exploration of my own interest, I could only turn my attention to the stars once more, this time in the daylight. I wanted to learn more about my constellation friends, the stars of Orion.

This exploration establishes how some of the stars in the constellation Orion are related to one another in terms of physical proximity. The distinction between the organization of the stars of a constellation (a mere appearance or pattern as seen from the earth) and that of the actual locations of the stars within our galaxy is made. My research question asks "Are the stars in the constellation Orion also in the same cluster of neighboring stars?"

My method to answer this was to select a number of the stars in Orion and then use an online database to find the parallax angle for each of the selected stars. Then I used a spreadsheet to calculate the distance to each star from the earth. Both a bar graph and a bubble graph are used to illustrate my conclusions. My results are then compared to distances found in other scientific databases.

While viewed as a constellation the stars of Orion are obviously grouped near one another and yet I found that some of the stars are indeed in the same cluster (in the same relative position in our galaxy) while others are not, and that Orion is made out of a number of clusters.

§ 2: CONSTELLATIONS & STELLAR CLUSTERS

While studying the Astrophysics option (my favorite topic) we learned about the distinction between a ***stellar cluster*** and a ***constellation***.

A **constellation** is an area of the sky containing a pattern of stars named after a particular object, often an animal or person. The word 'constellation' comes from the Latin, and means "stars together." [See "In Quest of the Universe" by Karl Kuhn (Second Edition, West Publishing Company, second edition), pages 16 and 17.] The stars in the recognizable pattern appear to be near each other in space (in their angular separation as seen from earth), but the stars in the constellation may or may not be in physical proximity.

In a stellar **cluster**, the stars are close enough to each other to be interactive by gravitational forces. In astronomical terms, they are physically close. There are clusters of stars and clusters of galaxies as well as super-clusters. There is no well-defined value to the proximity of stars and galaxies when they are called clusters and yet the term has significant meaning. [See "Star Clusters" pages 1-6 in Encyclopedia of Astronomy and Astrophysics, http://eaa.crcpress.com/] In general, a cluster of stars is created by the collapses of the same gas cloud and the stars interact by gravity.

Moreover, there are two types of star clusters: globular clusters are tight groups of hundreds of thousands of very old stars, while open clusters generally contain less than a few hundred members, and are often very young. This distinction is not relevant in my study. [http://www.sciencedaily.com/articles/s/star_cluster.htm]

The distinction here is between appearance and true location of stellar objects. A pattern of stars may consist of stars that are physically (in astronomical terms) far away from each other, but because of our perspective they appear to form a close recognizable patter, as if they are centrally located.

§ 3: SELECTION OF CONSTILATION & STARS

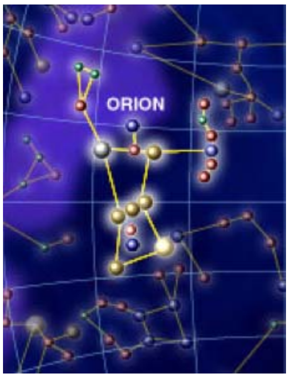
Although there are 88 recognized constellations in the night sky I selected one that is easily recognizable with the naked eye and is familiar to me as well as being popular throughout history. [http://starchild.gsfc.nasa.gov/docs/StarChild/questions/88constellations.html]

Orion is by far the most famous seasonal constellation. No other is more distinct or bright as this northern winter constellation. The famous Orion's Belt makes the 'hunter' easy to find in the night sky. I therefore choose a selection of stars from Orion as the object of my research.

§ 4: SOCIAL AND HISTORICAL DIMENSION

Orion, known as The Hunter, has been identified over thousands of years by many different cultures. Orion is among the constellations to work its way into classic texts. It is mentioned three times in the Bible, and is mentioned in the ancient Greek stories of the

Iliad and the *Odyssey*. ["Backyard Guide to the Night Sky" by Howard Schneider (National Geographic Publication, pages 214 and 215)]

	
Orion as a Mythological Figure http://media-2.web.britannica.com/eb-media/10/91710-003-5C0B4A1D.gif	**Orion as a Constellation** http://www.windows2universe.org/the_universe/Constellations/orion.html

§ 4: PARALLAX

Astrophysics is the marriage of physics and astronomy, and one key property of stellar objects is their distance from the earth. For thousands of years the method of parallax has been used to measure distances on earth. See the interesting online article "Distance: A History of Parallax" by B.J. Gillot. [http://www.bgfax.com/school/distance_history.pdf]

Parallax is the apparent shifting of an object against a distant background when viewed from two different positions.

This phenomenon can be used for distance measurements of both terrestrial and celestial objects. The stars form a pattern in the sky, and our view of the pattern depends on where and when we view the stars. We can use parallax to determine the distance of a near star against the background of more distant stars.

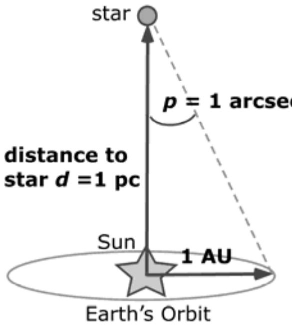
We need two viewpoints as far apart as possible if we are to see the greatest change in apparent position of a star relative to more distant stars. The longest baseline we can establish between two viewpoints is the opposite extremities of the earth's orbit about the sun, a distance of two astronomical units (2 AU). This occurs after the earth travels about the sun for 6 months.

Before the invention of the telescope the lack of noticeable parallax in stellar motion suggested that the earth was stationary and thereby the center of the universe. After the invention of the telescope the discovery of parallax helped prove that that earth is in motion and that the sun is at the center of our solar system.

§ 5: THE PARALLAX METHOD

The parallax method is useful for relatively close stellar objects; it is often quoted as being adequate up to a distance of 326 light years, that is, angles are measureable down to about

0.01 arc-seconds, where 1 arc-second is 1/3600th of a degree. Errors and uncertainties increase as distances increase because angles get smaller. ["Physics for Use with the IB Diploma Programme" by Gregg Kerr and Paul Ruth, 3rd edition, IBID Press, page 368.] Although the two observational positions of the earth relative to the sun for measuring parallax is over a period of 6 months, the parallax angle "*p*" is measured at one-half this displacement, just one astronomical unit (AU). The distance from the star to the sun is *d* and so $\tan p = 1\,\text{AU}/d$. When *d* >>1AU and the shift in the star's image is measured in seconds of arc, the stellar parallax *p* defines the distance *d* as $d = 1/p$. The unit of distance *d* is the **parsec** (pc). The name 'parsec' represents **par**allel angle of one **sec**ond.



$$\text{tangent} = \frac{\text{opposite}}{\text{adjacent}}$$

$$\tan p = \frac{1\text{AU}}{d} \approx \frac{1}{d}$$

The tangent of the angle and the angle in radians are approximately the same when measuring such small angles.

First: a full circle contains $360° = 2\pi\,\text{radians}$

Second: one degree in radians is $1° = 0.01745329252\ \text{rad.}$

Therefore: $\text{one arcsec} = \frac{1°}{60^2} = \frac{0.01745329252\ \text{rad.}}{3600} = 4.848136811 \times 10^{-6}\,\text{rad.}$

Here is the **tangent** of one arc-sec and the **angle** of one arc-sec when measured in radians.

$$\tan 4.848136811 \times 10^{-6}\,\text{rad.} = 4.848136811 \times 10^{-6} \quad \rightarrow \quad \tan p \approx p$$

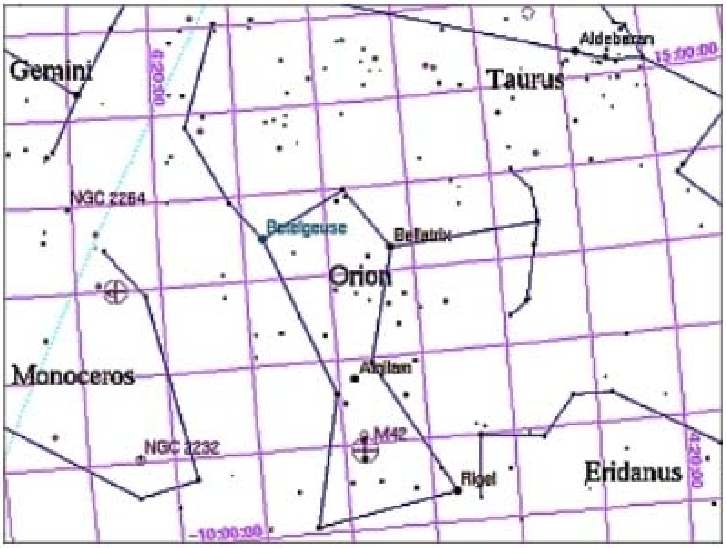
This tangent to angle approximation is more than justified as the uncertainty in measuring parallax is a number of magnitudes greater than the decimal places assumed in the approximation.

§ 6: ASTRONOMICAL DISTANCES

When an American 10¢ circular coin (diameter 17.9 mm) is 1.6 km away, it subtends an angle of one arc-second. This separation, of course, is not visible to the naked eye. In my work I converted parallax to distance and then to units of light-years. I used the conversion factors that were listed on page 3 in the IB publication of March 2007 called "Physics First Examination 2009 Data Booklet."

§ 7: SELECTING STARS IN ORION

My star selection contain the brightest and most noticeable stars in Orion. I selected: Betelgeuse, Bellatrix, Mintaka, Alnilam, Alnitak, Rigel and Saiph. See the star map below.



Stars of Orion

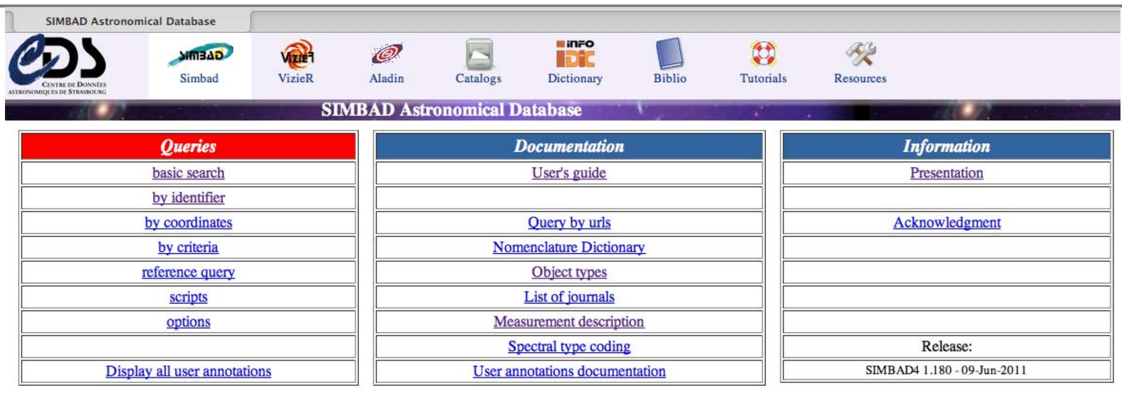
http://www.freewebs.com/dakotaskies/Orion-const.jpg

§ 8: ONLINE RESEARCH: PARALLAX DATABASE

My exploration used parallax measurement data found in the database called ***The Digital Library for Physics and Astronomy*** published online by the Harvard-Smithsonian Center for Astrophysics. This is a database used by professional astronomers. The web site of ***The SAO/NASA Astrophysics Data Base System*** is **http://adswww.harvard.edu/** and links from here connect to the actual data.

The search engine was at: http://simbak.cfa.harvard.edu/simbad/

The image below shows the online database. Requests for information can be entered either under ***basic search*** or by ***identifier***, depending on how much one already knows. I used the basic search, as shown below.



Using the SIMBAD astronomical database, I selected 'basic search' to find the parallax angles for my selected stars.

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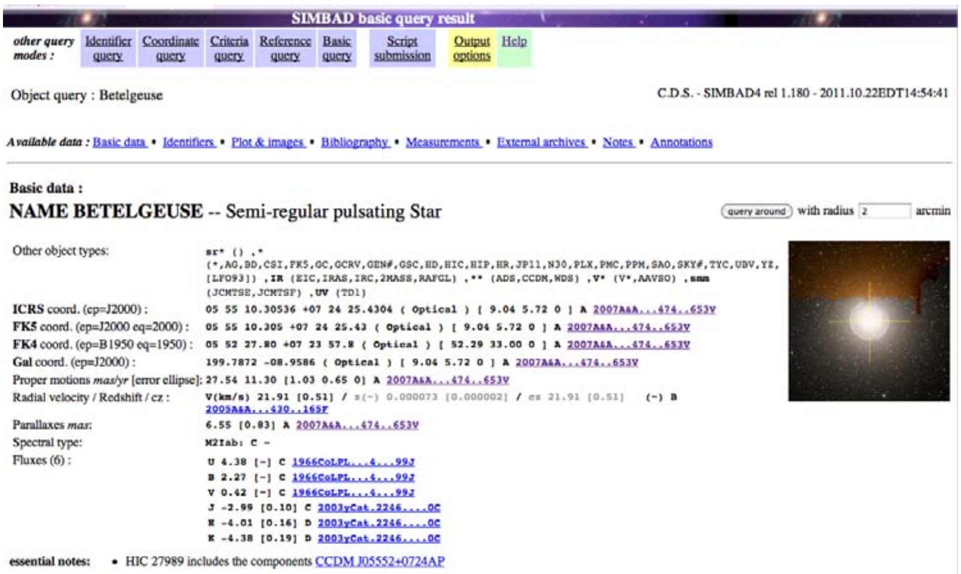
The next image is a sample of the data I obtained.



SIMBAD basic query result

other query modes : Identifier query | Coordinate query | Criteria query | Reference query | Basic query | Script submission | Output options | Help

Object query : Betelgeuse

C.D.S. - SIMBAD4 rel 1.180 - 2011.10.22EDT14:54:41

Available data : Basic data • Identifiers • Plot & images • Bibliography • Measurements • External archives • Notes • Annotations

Basic data :

NAME BETELGEUSE -- Semi-regular pulsating Star

query around with radius 2 arcmin

Other object types:	sr* () ,* (*,AG,BD,CSI,FK5,GC,GCRV,GEN#,GSC,HD,HIC,HIP,HR,JP11,N30,PLX,PMC,PPM,SAO,SKY#,TYC,UBV,YZ,[LFO93]) ,IR (EIC,IRAS,IRC,2MASS,RAFGL) ,** (ADS,CCDM,WDS) ,V* (V*,AAVSO) ,smm (JCMTSE,JCMTSF) ,UV (TD1)
ICRS coord. (ep=J2000) :	05 55 10.30536 +07 24 25.4304 (Optical) [9.04 5.72 0] A 2007A&A...474..653V
FK5 coord. (ep=J2000 eq=2000) :	05 55 10.305 +07 24 25.43 (Optical) [9.04 5.72 0] A 2007A&A...474..653V
FK4 coord. (ep=B1950 eq=1950) :	05 52 27.80 +07 23 57.8 (Optical) [52.29 33.00 0] A 2007A&A...474..653V
Gal coord. (ep=J2000) :	199.7872 -08.9586 (Optical) [9.04 5.72 0] A 2007A&A...474..653V
Proper motions *mas/yr* [error ellipse]:	27.54 11.30 [1.03 0.65 0] A 2007A&A...474..653V
Radial velocity / Redshift / cz :	V(km/s) 21.91 [0.51] / z(~) 0.000073 [0.000002] / cz 21.91 [0.51] (~) B 2005A&A...430..165F
Parallaxes *mas*:	6.55 [0.83] A 2007A&A...474..653V
Spectral type:	M2Iab: C ~
Fluxes (6) :	U 4.38 [~] C 1966CoLPL....4...99J B 2.27 [~] C 1966CoLPL....4...99J V 0.42 [~] C 1966CoLPL....4...99J J -2.99 [0.10] C 2003yCat.2246....0C H -4.01 [0.16] D 2003yCat.2246....0C K -4.38 [0.19] D 2003yCat.2246....0C

essential notes: • HIC 27989 includes the components CCDM J05552+0724AP

Here is a sample of the data for the star Betelgeuse.
The parallax angle reads (6.55 ±0.03) milli-parallex-seconds (mas)

§ 9: DATA

Data Table 1: Basic Data from Online Database

The following table shows the results of my research, parallax angle and uncertainty.

Star Name	Parallax / mas	Uncertainty / mas
Betelgeuse	6.55	±0.83
Bellatrix	12.92	±0.52
Mintaka	4.71	±0.58
Alnilam	1.65	±0.45
Alnitak	4.43	±0.64
Rigel	3.78	±0.34
Saiph	5.04	±0.22

§ 10: CALCULATIONS

Although I used a spreadsheet to convert milli-arc-seconds (mas) to light years (ly), the following illustrates the calculations for Betelgeuse.

First, convert milli-arc-seconds (mas) to arc-seconds (as): $6.55\,\text{mas}\left(\frac{1\,\text{as}}{1000\,\text{mas}}\right) = 0.00655\,\text{as}$

Then calculate distance in parsecs (pc): $d \approx \frac{1}{p} = \frac{1}{0.00655\,\text{as}} = 152.67\ \text{pc}$

Finally, calculate the distance in light years (ly): $152.67\,\text{pc}\left(\frac{3.26\,\text{ly}}{\text{pc}}\right) = 497.71\ \text{ly}$

Here is a screen shot of my results by a spreadsheet within *Logger Pro* 8.3.4 for the Mac computer graphing software by *Vernier*. See http://www.vernier.com/

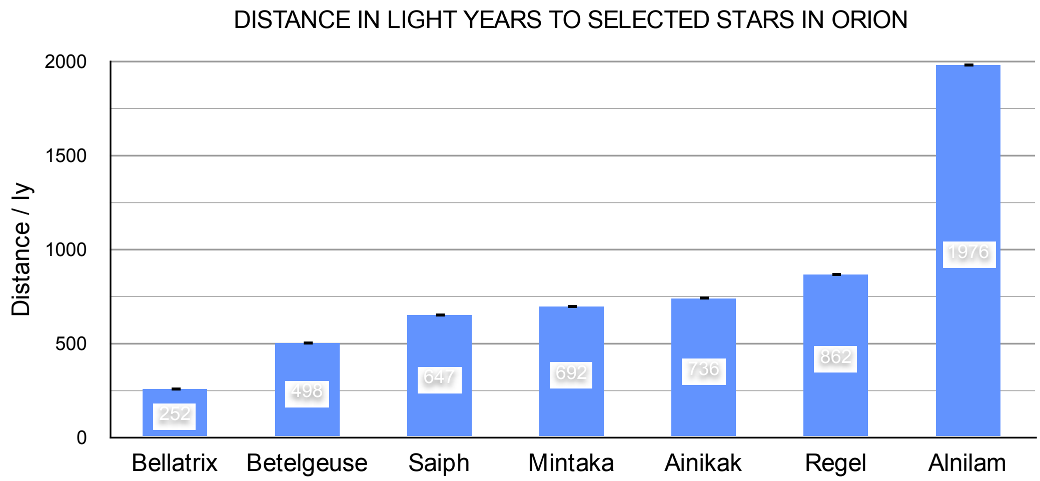
Data Table 2: Spreadsheet Calculation for Distances.

	Data Set				
	NAME OF STAR	P (mas)	P (as)	D (pc)	Distance (ly)
1	Betelgeuse	6.55	0.0065	153	498
2	Bellatrix	12.92	0.0129	77	252
3	Mintaka	4.71	0.0047	212	692
4	Alnilam	1.65	0.0016	606	1976
5	Alnikak	4.43	0.0044	226	736
6	Rigel	3.78	0.0038	265	862
7	Saiph	5.04	0.0050	198	647

Distances are given to a precision of one light year only, as when I consider the uncertainties, the error will be even larger than this.

§ 11: GRAPH OF DISTANCES OF SELECTED STARS

Graph 1: Distance of Stars in Orion in Increasing Distance Order



By looking at this bar graph I made the following conclusions about possible clusters of Orion stars. From a qualitative view, then, Mintaka, Alnikak, Regel and Saiph form an apparent cluster; then Betelgeuse, Bellatrix, Alnilam are non-clustered stars; and the farthest star is Alnilam and the nearest is Bellatrix.

§ 12: UNCERTAINTEIS IN GRAPHED DISTANCES

Next I consider the uncertainties of each measurement as given in the database. This is contained in the first three of the four columns below. I assume that these values used by professional astronomers are justified. I converted the absolute uncertainty into a percentage for the last column.

Data Table 3: Uncertainties in Database Values

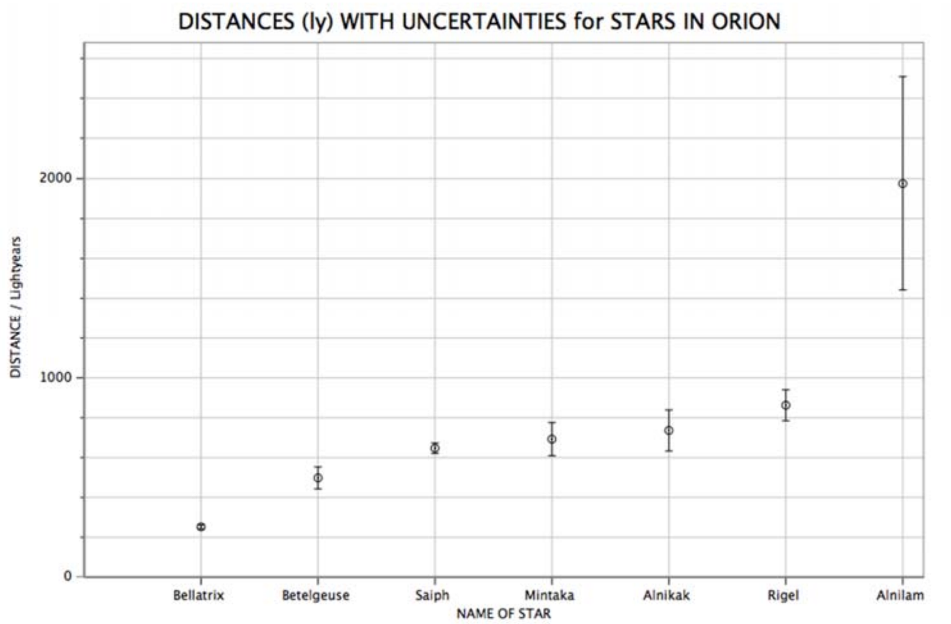
Star Name	Parallax / mas	Uncertainty / mas	Uncertainty / %
Betelgeuse	6.55	±0.83	13
Bellatrix	12.92	±0.52	4
Mintaka	4.71	±0.58	12
Alnilam	1.65	±0.45	27
Alnitak	4.43	±0.64	14
Rigel	3.78	±0.34	9
Saiph	5.04	±0.22	4

The database gave me the absolute uncertainties. The percentage was a basic calculation in the spreadsheet; an example calculation for Betelgeuse is shown below.

Given in Database: (6.55 ± 0.83) pc hence $\frac{0.83}{6.55} \times 100 = 12.671\% \approx 13\%$

Then, because the conversion of parallax angle to light-years involves only mathematical manipulations, I keep the percentage of the initial angle as the percentage of the calculated distance. Next the distances of each star were plotted and uncertainty bars were added (see Graph 2 on the below). Uncertainties range from large (for the farthest start) to small for nearer star.

Graph 2: Distance of stars in Orion with Uncertainty Bars.



Next (see Graph 3 on the next page) I graphed the relative positions of my stars on a bubble-graph, where the size of the data point relates to the distance of the stars from the earth: a large bubble means the star is near, and a small bubble means it is far. I assumed the stars were all equal in size (which they are not).

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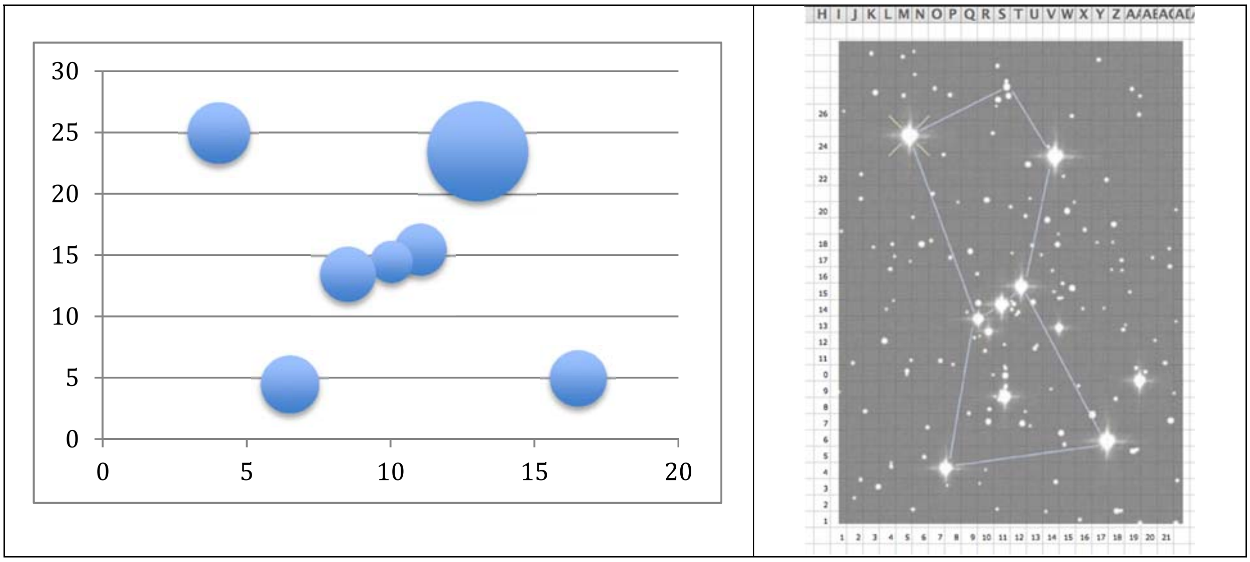
Graph 3: Orion Bubble Graph.



The scale (on Graph 3) is arbitrary. I simple imported an image of Orion into Excel, then marked cell boxes with arbitrary but linear numbers for the horizontal (normally degrees from the horizon) and arbitrary numbers (again for a linear scale) for the vertical (the hour angle, the distance of the westward along the celestial equator). Because stars appear as points of light it is appropriate to assume they are all the same diameter and hence represent the data points as a function of the star's distance.

§ 13: CONCLUSION

Obtaining parallax angles from a professional astronomical online database allowed me to calculate the distances to selected stars in the constellation Orion. I graphed the stars in a bar graph in order from near to far, and I was thus able to estimate which star may be in a common cluster and which stars were not.

The stars Mintaka, Alnikak, Regel and Saiph appear to be in the same cluster, the same proximity of space. The star Alnilam is clearly far away from the other Orion stars. The stars Betelgeuse and Bellatrix are nearest the earth but not in the same proximity with each other or the other stars. I was really excited to figure this out, as I have long enjoyed observing Orion and now I know my friends even better.

There is no well-defined measurement for the proximity of cluster stars so there is no way to improve my estimate in my conclusion. More data would add more stars, and this would be interesting. The given uncertainty in the data is as good as it gets, so from my point of view there is no way to improve this.

One alternative that occurred to me after I finished this investigation was to simply look up the stellar distance. Although this was not given in my database, the distances of the stars can be looked up online. It is too late now to follow this up.

§ 14: EVALUATION AND IMPROVEMENTS

My method and source of data were straight forward, and no techniques can be imagined to improve this investigation. However, I assumed the data was accurate to the given degree of uncertainty. I was so focused on the parallax method that it never occurred to me to simply look up the distances. For my comparison analysis, then, I obtained distance data from two online sources, Space.Com, and the Sloan Digital Sky Survey, both reputable scientific information sources. Taking the average of these two and comparing the distance to my calculations, I established the error of my values compared to so call accepted values. So called, because these sources listed no uncertainties.

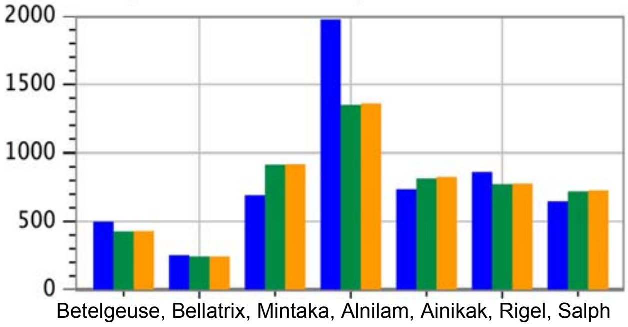
Data Table 4: Distances

Star	My Distance (ly)	Sloan	Space.Com
Betelgeuse	498	427	429
Bellatrix	252	243	243
Mintaka	692	916	919
Alnilam	1976	1350	1360
Ainikak	736	815	826
Rigel	862	773	777
Salph	647	720	727

http://www.space.com/3380-constellations.html

http://cas.sdss.org/DR3/en/proj/kids/constellations.html

Graph 4: Distance to Star in Light Years
My Data, Sloan Data, Space.com Data



Notice that the first column of each star in Graph 4 is my calculated distance, the center column is the Sloan data and the column on the left is data from Space.com. My results vary from a large amount to very little. I do not know how the values of distance were calculated for this comparison. The greatest different is with Alnilam, but here my parallax angle had an uncertainty of 27% or 534 ly. At the worst, this would be 1976 – 534 = 1442 ly, which is slightly beyond the Sloan-Space.com average of 1355 ly. However no uncertainties were listed so my distance and the comparison may well overlap. The least difference was for Bellatrix, at only 0.4% difference; a typical difference was Salph at about 10% difference. Overall, I consider my results satisfactory.

An improvement in the presentation would be to construct a 3-dimensional graph where the Orion image appears on the x-y axes and then on the z-axis the distances would be indicated. The three-coordinate image could then be rotated about in order to change the image from the well-known Orion pattern to a perspective revealing the physical distances of the stars relative to the earth.

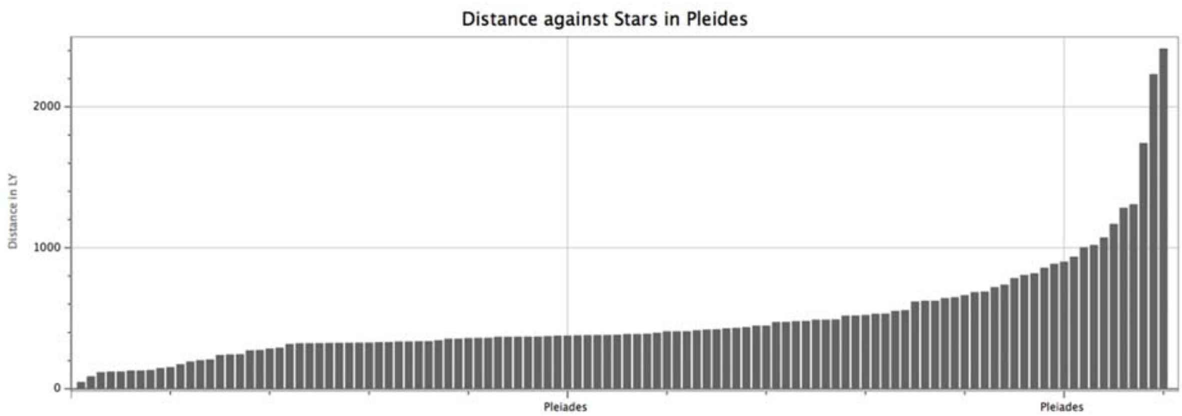
§ 15: FURTHER STUDIES

First, I could make another bubble graph but with the stellar information about the **star's size** (each star has a different radius) or the star's **absolute magnitude** (or apparent magnitude). These would be interesting to me.

Second, now that I have perfected the method of distance measurement of stars, I would like to analysis a large amount of data. I could easily copy the stellar information for over one hundred stars in The Pleiades. I found this data on the Internet at the "EEPS DATA ZOO". Here is the data for the first 13 stars of over 100 in The Pleadies. I could plug this into the Excel or Logger Pro software and create more interesting graphs. Here is a hint at this.

	Data Set												
	V	RA	DEC	C 2 (mas)	PM RA	C 4	B V	V I	C 7	mas to	one	CC (LY)	Distanc
1	9.61	56.58	26.21	68.62	386.9	-198.	1.437	1.77	Pleiad	0.069	14.57	47.50	47.50
2	7.57	58.02	22.67	37.25	207	-340.	0.684	0.74	Pleiad	0.037	26.84	87.51	87.51
3	8.78	59.44	22.92	27.72	157.3	11			Pleiad	0.028	36.07	117.6	117.6
4	7.29	57.51	22.59	26.91	155.0	-63.5	0.538	0.61	Pleiad	0.027	37.16	121.1	121.1
5	7.28	54.29	25.99	26.78	237.5	-271.	0.704	0.75	Pleiad	0.027	37.34	121.7	121.7
6	6.77	58.04	25.16	25.34	-121.	-163.	0.583	0.65	Pleiad	0.025	39.46	128.6	128.6
7	9.35	54.39	21.34	25.23	141.5	-27.3	0.917	0.96	Pleiad	0.025	39.63	129.2	129.2
8	10.17	57.76	23.90	24.72	150.9	-46.6	1.16	1.12	Pleiad	0.025	40.45	131.8	131.8
9	5.62	59.21	22.47	22.31	69.43	-114.	0.345	0.4	Pleiad	0.022	44.82	146.1	146.1
10	7.84	59.11	22.67	21.41	174.2	-233.	0.688	0.75	Pleiad	0.021	46.70	152.2	152.2
11	7.4	55.56	22.78	18.79	21.57	-75.5	0.428	0.5	Pleiad	0.019	53.22	173.4	173.4
12	5.24	57.57	25.57	16.96	36.37	-117.	0.231	0.26	Pleiad	0.017	58.96	192.2	192.2
13	6.98	56.82	23.72	16.1	-34.0	-25.3	0.542	0.62	Pleiad	0.016	62.11	202.4	202.4

Data from: http://www.eeps.com/zoo/cages/Pleiades.html.



I do not include the name of the stars here; it is just interesting to see the relative distances from the earth (and to demonstrate the ease of calculations using a spreadsheet).

The End