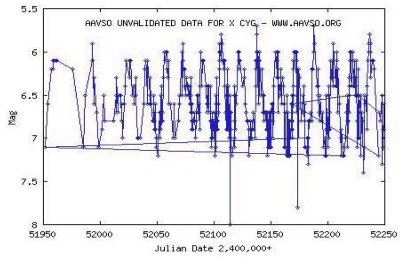
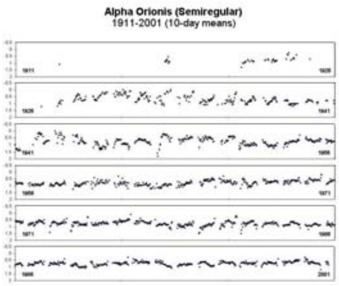


ASTRONOMY PROJECT

CEPHEID VARIABLES

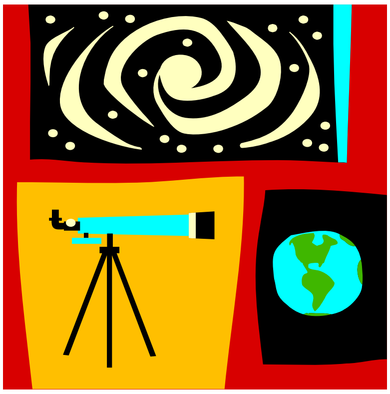
Why do supergiants pulsate in instability region neither than others?

DERYA SÖZEN
L1A / 48



MÜGE GENÇ

CONTENTS



INTRODUCTION

In this project, I am looking for an answer to “Why supergiants pulsate in instability region neither than other?”. I want to learn why they pulsate and why there is a change in their brightness. During my observations I used CCD and by the help of Pictor, Vision and Guide computer programs, I got my data.

During my project I use a cepheid variable named X CYG. With this variable, I will show that the supergiants passing through Cepheid Belt are pulsating. For my comparison I will also use Betelgeuse from Orion constellation and Deneb from Cygnus constellation.

The reason I use these is because Deneb is a supergiant as same as X Cyg and it will come to Cepheid belt and on the other hand Betelgeuse is a supergiant that passed this Cepheid Belt. So it will be easy for me to show that they just pulsate during passing this instability region, with my comparisons.

Now, let’s find out this together more deeply step by step.

American Association of Variable Star Observers: AAVSO

The AAVSO, the world's largest variable star organization, has been serving amateur and professional astronomers since 1911. We can join this organization and become a valuable part of the continuing research in variable star astronomy just by making only a few hours of observations each month!

General Information: AAVSO is a non-profit worldwide scientific and educational organization of amateur and professional astronomers who are interested in stars that change in brightness- variable stars. The AAVSO was founded in 1911 at Harvard Collloge Observatory to coordinate variable star observations made largely by amateur astronomers and to make these observations available ro professional astronomers. In 1954, the AAVSO became an independent, private research organization. Today with members in 46 countries and headquarters in Cambridge, Mass., USA, it is the world’s largest association of variable star observers.

Research on variable stars is important because it can provide much information about stellar properties, which can then be extrapolated to other types of stars. Information about mass, radius, internal and external structure, composition, temperature and luminosity can be gained by the study of variable stars. At last another thing to say is that the archives of the AAVSO currently over 8.5 million observations.

CEPHEID VARIABLES

One important class of pulsating variables is the Cepheid variables. The Cepheids are supergiants, in general of luminosity class Ib; on the Hertzsprung-Russel Diagram they occupy a narrow, steep strip, slightly inclined towards the right. Spectral classes are F5 and K0 (Look at pg.17 for Spectral Classes). Longer periods are associated with later spectral class and greater color index. These large yellowstars pulsate from 1 to 70 days, with an amplitude of light variation up to 2 magnitudes. They are intrinsically very bright. The greater the absolute magnitude of a Cepheid, the longer its period. In fact, there is a strict relationship between a Cepheid's period and its luminosity, called the period-luminosity relationship. We can determine the period of a Cepheid from its light curve, then using the period of the Cepheid, we can apply the period-luminosity relationship to compute the Cepheid's luminosity. Knowing its magnitude (how bright it appears to observers on Earth) and its luminosity (how bright it actually is) allows us to compute its distance from us, thereby enabling us to use Cepheid variables as distance markers. We can measure the distance to any given galaxy by computing the distance to its Cepheid variables.

But in fact, there is an another thing that's strange. All stars born and die. Their birth is all same, but against to their mass, their rest of the life and their end is different. So we have to find out why cepheid variables are staying in indecision region more than some of their twin stars.

HOW IS THE EVOLUTION OF A SUN-LIKE (dwarf) and A SUPERGIANT STAR

In the very beginning, gas and dust particles collapse by their own gravity in the nebula. As a result of this fact, temperature rises and after a limit of temperature, the star is born as a proto-star. If the mass of the star is greater than the critical mass, a reaction from hydrogen to helium starts in its core.

During this reaction hydrogen is changed into helium and when the reaction ends, there will be a helium core and hydrogen gas around it, with the other particles. Then with the end of the reaction, star starts to collapse towards its core and when density gets high, the necessary temperature occurs.

The following step is, with the help of necessary heat in the core, the reaction again starts as helium to carbon. Again the same process occurs as hydrogen to helium reaction. Also carbon is a more powerful element than hydrogen, because of that it will get bigger now. For dwarf star; After, carbon should be converted into sodium(Na), but this time another reaction will not begin. The reason is that, the necessary heat would not be obtained in the core to start the reaction.

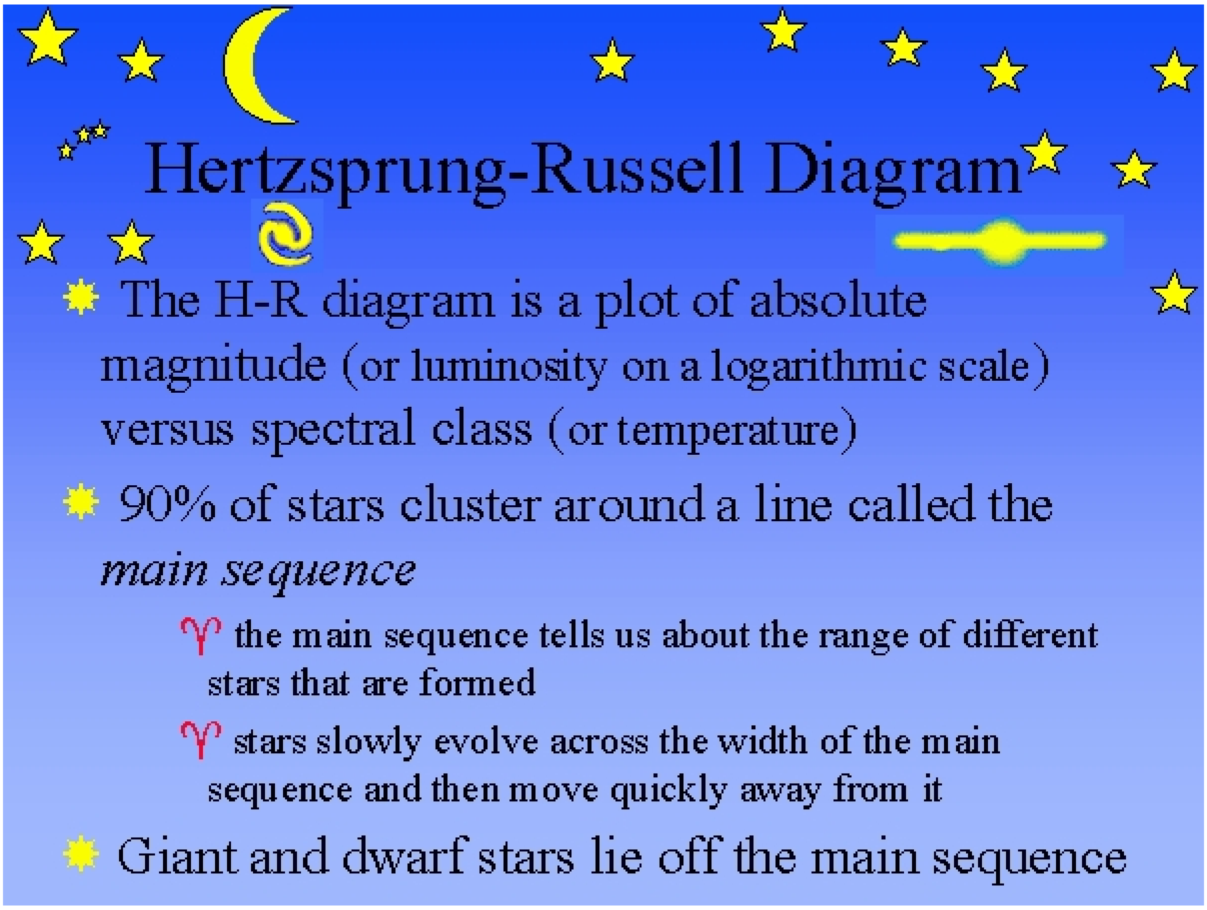
So now we can say that, star died because there is no reaction anymore. However, by increasing density, there will be an explosion which we call Type I Supernova explosion. This explosion will not be as powerful and effective as Type II Supernova, because our star’s mass is less, it is a dwarf star. Then it will form a planetary (ring) nebula and it will be the white dwarf at the center of this nebula.

If our star is a supergiant then the reaction in its core will end with Iron(Fe). After Iron the necessary heat wouldn’t occur that’s why it will collapse towards its core and then there will be a Type II Supernova explosion.

As you see, against to their masses stars have different lives and different ends. Some of supergiants evoluate differently, too.

Massive stars

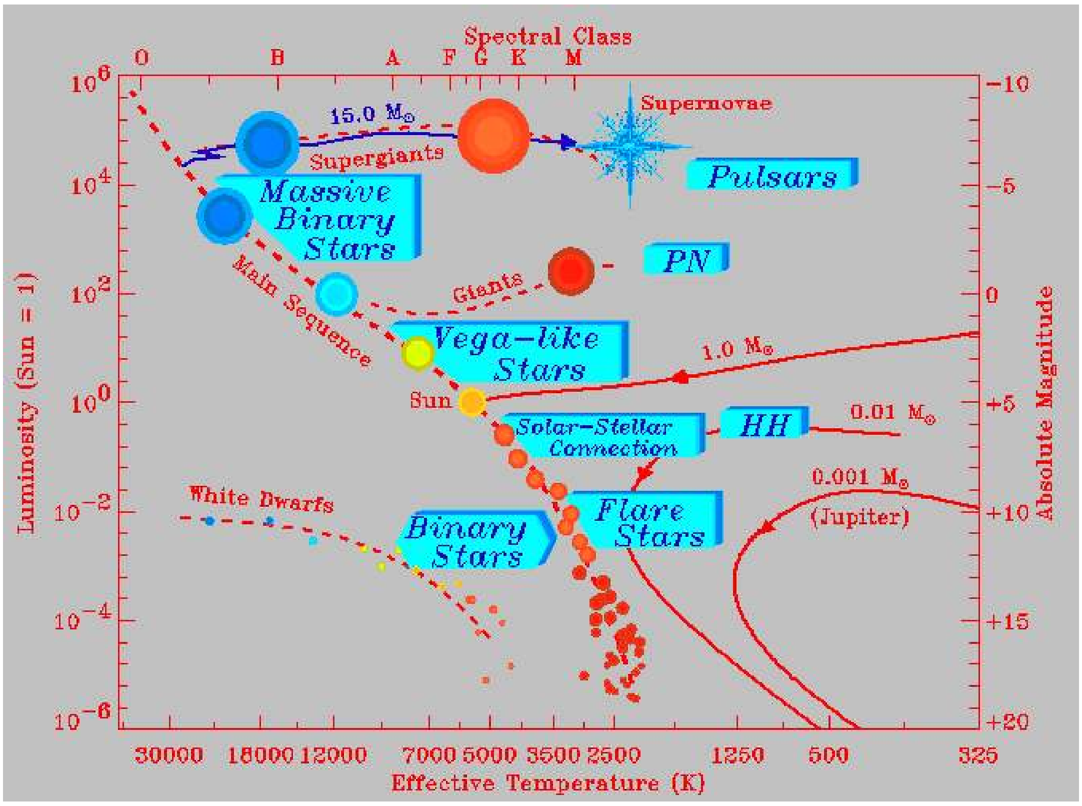
There are several types of star with masses greater than 1.5 that are known to be oscillating. Examples are Scuti stars, which populate the low-luminosity extension of the Cepheid instability strip, with periods ranging from 20 min. to a few hours. There are also the slowly pulsating B stars (periods are between 1 and 3 days), oscillating Be stars, with periods between 0.5 and 2 days, and Cephei stars, whose periods range from 2 to 8 hr. All these stars are multiperiodic, and most, if not all, B-type variables owe their pulsations to the kappa mechanism operating in the metal-opacity bump. It is firmly believed that in any given star the modes that have so far been observed represent only a small fraction of the modes that are actually excited. The reason is that the amplitude-limiting mechanism of the modes observed involves a draining of energy into other modes of oscillation of yet lower amplitude. Our confidence in this conclusion stems from the fact that in the case of Cepheids, where only one or two modes are involved, the theory predicts amplitudes large enough to be observed, and it has thus been possible to confirm its validity.



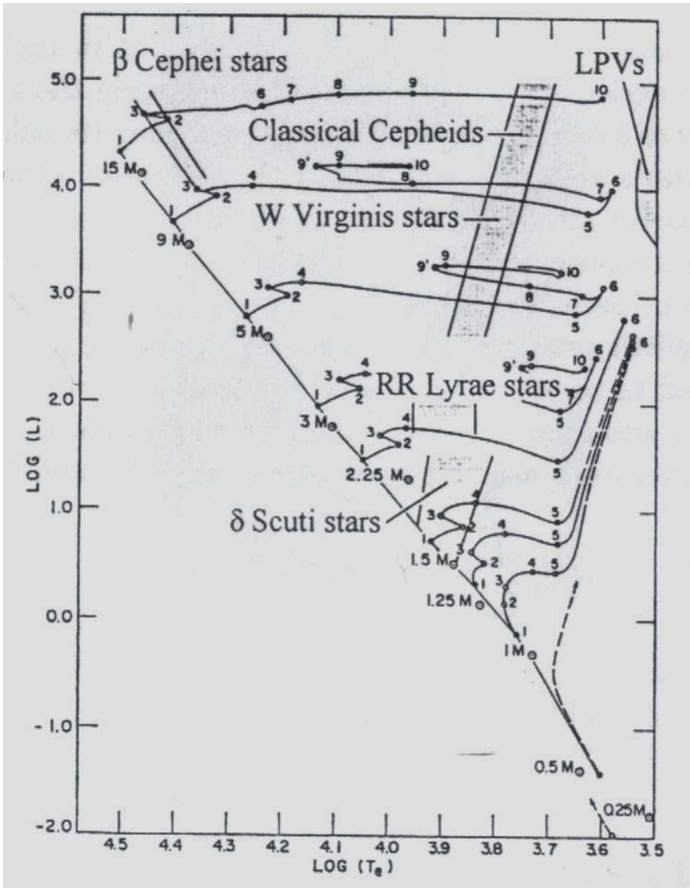
What is the Hertzsprung-Russell diagram?

The H-R diagram is a way of showing the main properties of stars on a chart usually plotted with the star's colour, or spectral type along the bottom axis, and its brightness, or absolute magnitude up the side. The positions of actual stars can be plotted on the diagram, and the patterns we find can teach us a lot about the life cycle of stars.

Most of the stars on the H-R diagram are in a band from bottom right to top left; that is, from dim red stars to bright blue ones. This strip is called the main sequence, and the stars are concentrated here because it is where they spend most of their lifetimes, during the long period when they burn hydrogen in their core. Although the main sequence looks like a path which stars could move up or down, it is not, actually - a stars position on the band is fixed throughout its main sequence lifetime, and depends on its mass - low-mass stars tend to be dim and red, high-mass stars are bright and blue. The colour of a star is related to how hot its surface is - in the same way that an iron bar heats up from red to white to blue heat. The Sun, a star with fairly average mass, lies in the middle part of the main sequence, with other yellow-white stars. the path on the diagram shows the typical life of a star like the Sun, from its collapse, and slow heating in a gas cloud, through its main sequence lifetime, and beyond that to the distant future, when it will eventually run out of fuel at its core, and swell to a red giant, slowly increasing its brightness as it does so.



❖ In my project I have to use Hertzsprung-Russell Diagram, because I will show which group of star is passing through which belt and what those stars are. I will see their masses, passing process and the way they use.



- Pulsating stars on the H-R diagram. The evolutionary tracks are incomplete, and those of the lower-mass stars extend into the LPV (long period variable) region.
- H-R diagrams are showing us which class of star goes into which group for variable's belt. For example: here is we can say that between 9 M_O and 15 M_O Super giant stars are passing through Cepheid Belt.
- The stars that has less mass are passing through another type of pulsating variable's belt.

❖ From the beginning, we learn some informations about Cepheid Variables, Evolution of a Star, X Cyg and Hertzsprung-Russell Diagram. Now we can find out the reason of why some supergiants that we call Cepheid Variables, are staying in that instability region more than others.

ORIGIN OF PULSATION AND EVOLUTIONARY STATE

It is definitely established that is primaly the outer layers of the which pulsate. The fundamental cause was first recognized about 1960, after many authors had performed important preliminary work. It is not, as was at first thought, that once pulsation has been initiated it continues to regulate the energy production in the deep interior of the star for evermore nuclear processes being, as is well-known, very temperature-sensitive. It is rather that the *absorption characteristics* of the outer layers maintain the pulsation. The process has sometimes been called the *Kappa Mechanism*.

In the main it is the zone where helium is doubly ionized, lying a few hundred thousand km below the stellar surface, which is responsible for driving the pulsation. Within this zone, helium is increasingly ionized as the temperatue rises towards the interior, eventually becoming completely ionized. With a slight compression such as can always occur through some small disturbance, that is with an increase in pressure and temperature, there is a rise in the absorption of radiation within this zone. This additional energy over-compensates for the normal heat loss found in stable stars (which has a damping effect), and the expansion of the affected laters of gas overshoots the original rest position. This expansion now produces the opposite effect to that just described and an undamped oscillation results. In principle this can persist as long as the general evolutionary process maintains the dimensions and properties of the excitation zone within the star. Various criteria can be used to determine whether a particular, theoretical, stellar model gives rise to pulsational variability.

The evolutionary state of the Cepheids stars is fairly well-understood from extensive series of *model calculations*. They are objects in whose centres hydrogen has been completely transformed into helium. Differing interpretations merely vary in the extent to which the triple-alpha process has already enriched the stellar core with carbon. HOFMEISTER worked from the hypothesis that energy production is primarily taking place at the outermost layer of the “burn-out” carbon core through further transformation of helium. In their classic work on objects of 7 solar masses these authors discovered, in the models considered, the multiple changes which occur in the overall evolutionary expansion and contraction of the outer layers. These changes have now been well-investigated and are seen on the Hertzsprung-Russell Diagram as multiple reversals in the evolutionary track.

Cepheid stars are undoubtedly objects where energy production is taking place within a still-existing helium core. All calculations are in very good agreement with the observational evidence that it is at this evolutionary stage that the tendency to pulsations appears, and that the stars are only found within the region of the H-R Diagram known as the *instability strip*. Massive stars reach this region considerably earlier and at a somewhat different position than the objects of just a single solar mass.

Causes of the Changes in Brightness

As already intimated, an exhaustive explanation is still missing. It is certain that a *pulsation* is involved. But there is yet another cause involved, which is that of *changes in the transparency* of the outermost layer to visual radiation, due to the formation of *carbon particles*, which are also now considered to play a part in instellar extinction. As a result the stellar atmospheres would be dimmed by “smoke” or “soot”, recurring periodically and controlled by the pulsations. The energy absorbed by this layer would be re-radiated in the longer-wavelenght region as heat. This would explain the small bolometric amplitude. As already mentioned, maximum light corresponds to minimum diameter, in other words to the maximum density of the outer layers. However, this makes certain assumptions about the dissipation in such an absorption layer.

One fact plays a large part; supergiants lie close to the natural stability boundary, and under the physical conditions in this region very small variations in the flow of energy coming from the interior of the star may be sufficient to produce large effects in the outer layers.

Strange Cepheids driven by the kappa-mechanism

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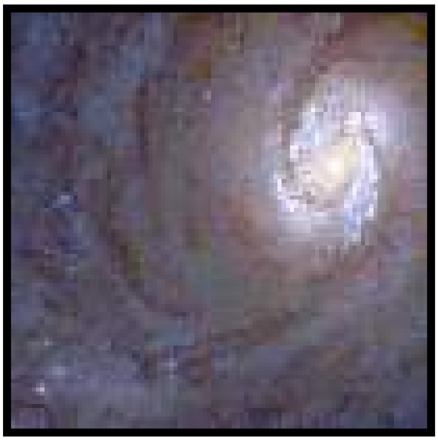
Why do some stars pulsate?



Most of the pulsations are considered to be caused by the kappa-mechanism. "kappa" is for opacity.

In most of the inside of stars, the opacity of stellar gas decreases as temperature increases. However, there are some regions where this tendency gets weak, or even gets reverse. For example, in the hydrogen and helium ionization zones, opacity increases as temperature increases. These zones, especially helium ionization zones are considered to be the exciting regions of the classical Cepheids, RR Lyrae etc. Recently, a small bump of the opacity caused by metals is recognized. This bump is considered to be responsible for the beta Cephei type and some higher effective temperature pulsators.

Let's consider that the gas in the ionization zone is compressed by a perturbation. The density and temperature of this zone increases and the opacity also increases. Then, the energy flux from inside of the star decreases because of the increase of opacity. This energy flux decrease causes the extra heat energy comparing with the adiabatic change. Then, this region obtains extra restoring force by this extra heat energy.

When the gas in this region is expanded, opacity decreases. This decrease causes the extra energy loss and again obtains extra restoring force.

The region where there is an opacity bump is unstable to the pulsation. However, most of the stellar envelope is stable. If the effect of destabilization is larger than that of stabilization a star will pulsate as a whole.

Please remark that above described kappa mechanism works when the most of the energy flux is transferred by radiation. When the convective transfer becomes dominant process, the pulsation will not occur. This is considered to be the origin of the red edge of the pulsation in the HR diagram.

If the effective temperature of a star is high enough, the density of ionization region is too low, and the destabilizing effect is too small. This is considered to be the origin of the blue edge.

OBSERVATIONS

<u>CCD (Charged Couple Device) – Meade Pictor 416 x T</u>

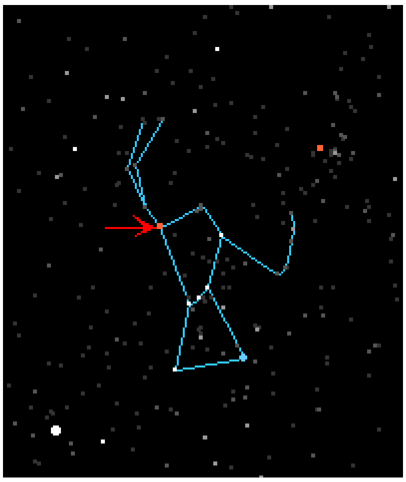
The 416XTE includes more than *four times* the pixel quantity, more than *twice* the pixel density, and about *one-tenth* the dark current of competing units. The result is high-resolution images of the Moon, planets, and deep-space with amateur telescopes that match or exceed the photographic images obtained with many observatory telescopes. The Pictor 416XTE is truly the amateur astronomer's dream of incredibly fast, professional-level imaging capability.

Computer Programmes

Guide : More detailed star finder programme.

Pictor : CCD control software

Vision : Determining Magnitude and Workings on the Image

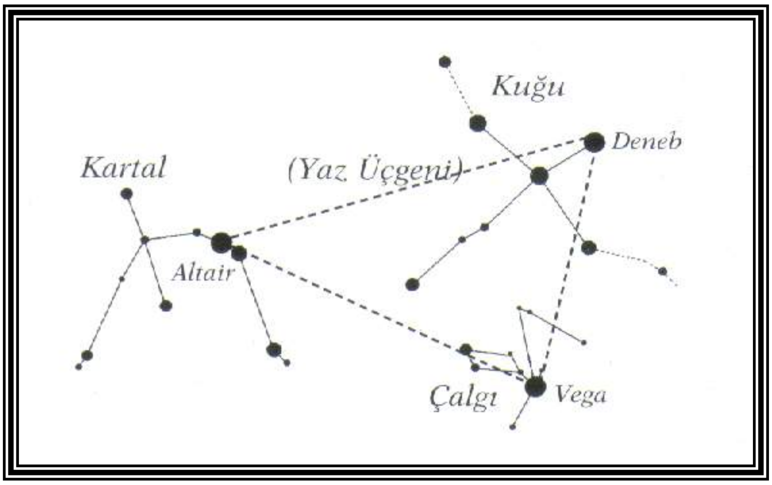


Betelgeuse (Alpha Orionis)

Distance (Light Years)	427 ± 92
Visual Magnitude	0.45
Color (B-V)	1.85

BETELGEUSE, The great star Betelgeuse is one of the two that dominate mighty Orion of winter

The Red Supergiant



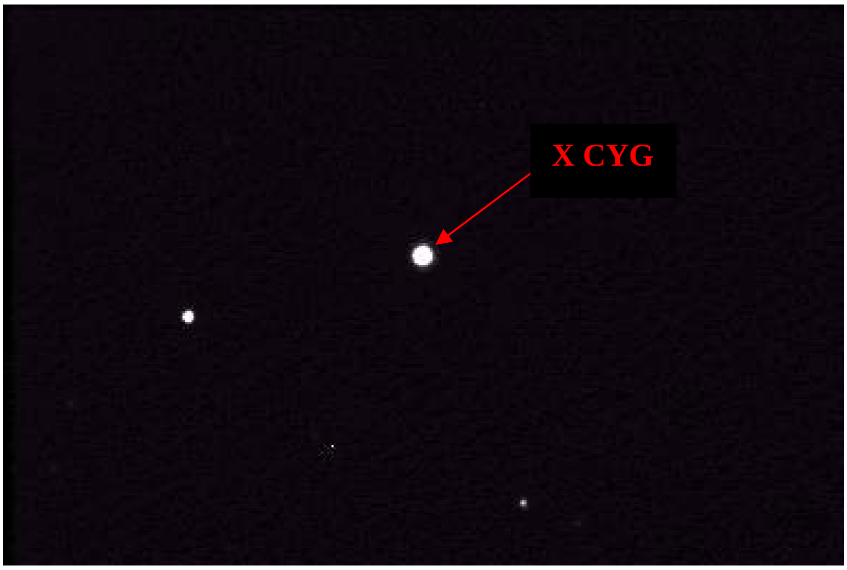
DENEB, simply put, is one of the truly great stars of our Galaxy.

Visual magnitude: 1.33

Distance: 3262 +/- 2007 light years

Luminosity: 238122 +/- 383250 x Sun's luminosity

- ***X CYG*** *is my classical type Cepheid Variable that I will work on. It is in Cygnus Constellation and a supergiant star. Cygnus constellation can generally be observed in summer season.*



Star	Period	Spectral class
SU Cas	1.94	F5 – F7
δCep	5.37	F5 – G2
ηAql	7.18	F6.5 – G2
ζGem	10.15	F7 – G3
* X Cyg	16.38	F7 – G8
T Mon	27.01	F7 – K1

❖ *Before Begin To Observation...*

Polar Setting : After opening the telescope, we set declination 90° and RA 0° . Then we found polar star and middle it, we press ENTER from our keypad. After this telescope wants us to find a star to correct our setting. We find the coordinates of star from Guide (the computer programme) and enter it to keypad. If it finds it well then our polar setting is correct,too. We can find whatever we want just by entering its codes to the keypad.

During Our Observation

To take images we use CCD camera as shown in the picture beside. After we found our variable star with the help od Guide, by using Pictor we got the image and then by working on it in Vision, we found its magnitude.

Graphs and Explanations

X

C

Y

G

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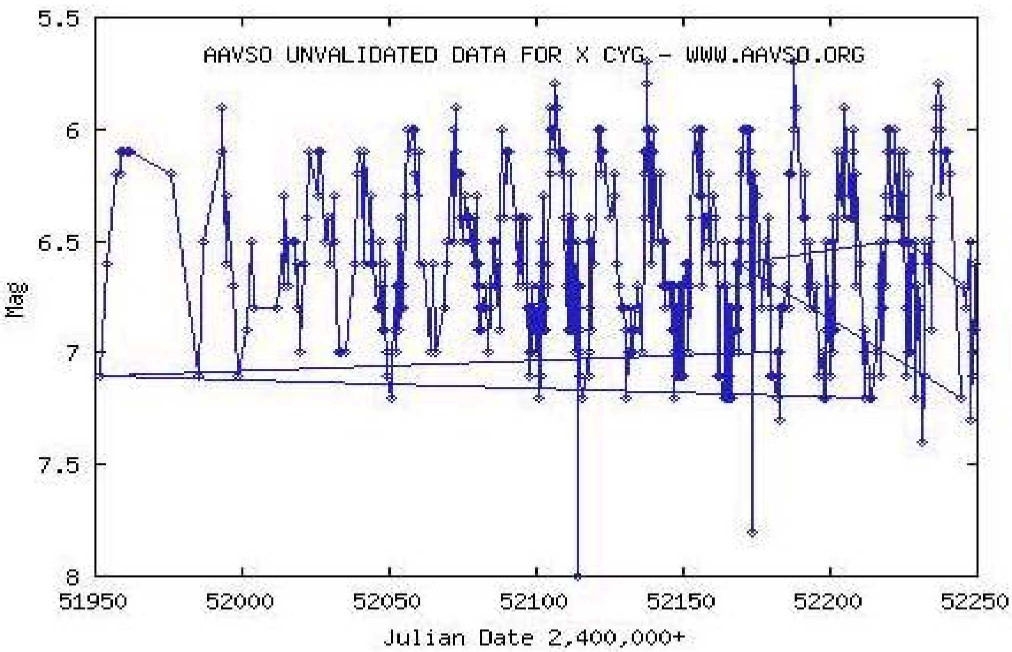
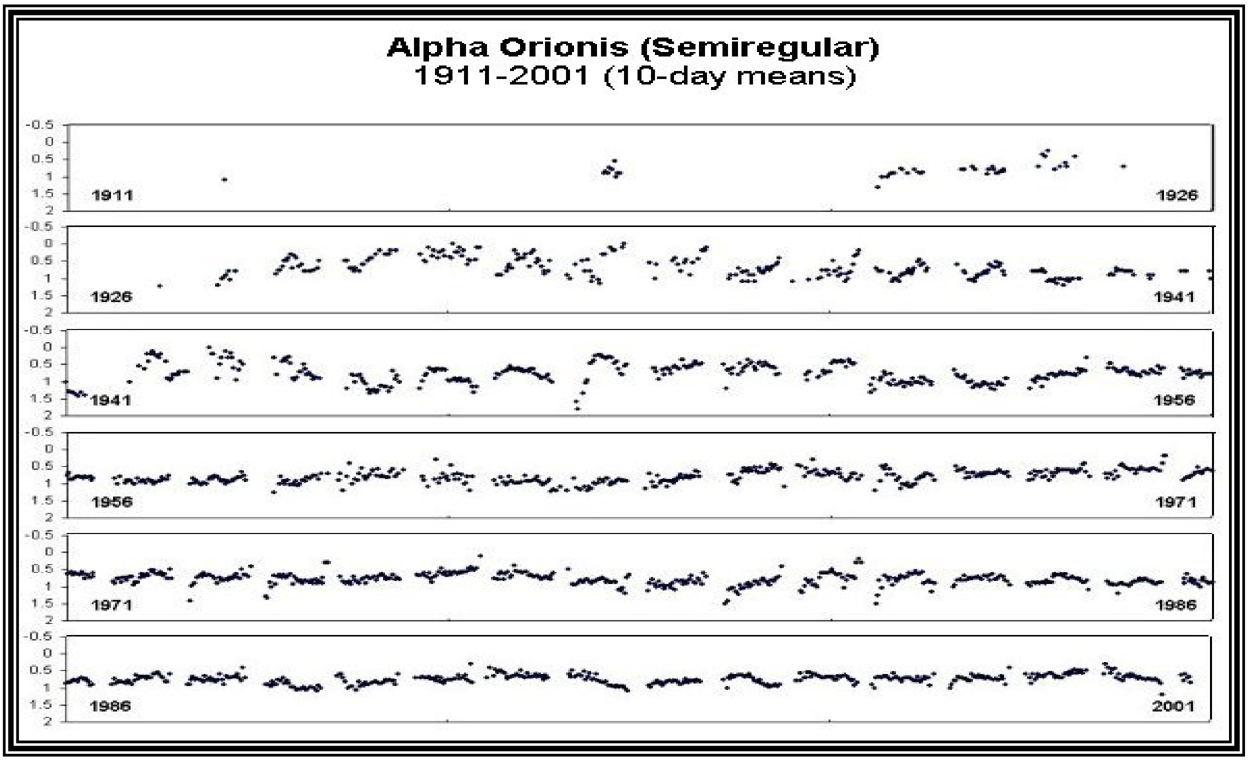


- *As we can see from this graph, that X CYG change in brightness in a time period. Remember that X CYG is our Cepheid Type Variable Star (pulsating star) that pass through Cepheid belt (instability region).*

BETELGEUSE



❑ We know that Betelgeuse is a star that finishes passing through Cepheid Belt. Now may be it is still under the effect of pulsation, but after time passes it is becoming more stable. We can get it from the graph, too.

DENEB : It is not possible to find a light curve of Deneb. Because It is not a varibale star and also it does not come to Cepheid Belt or passes it yet. So Deneb does nor pulsate, it is a stable star. It does not have any change in brightness.

CONCLUSION

The Question was: Why supergiants pulsate in instability region neither than others? After all of my searchings I nearly found the absolute answer for this question.

The Cepheids are pulsating variables. The radius and the surface temperature of a Cepheid change periodically so the overall brightness varies.

There is a Cepheid Belt also shown in the H-R diagram that massive stars pass during their evolutionary states. The reason of the pulsation of these star is the absorption characteristics of the outer layers. More deeply, the reason of this absorption is; In the main absorption layer is the zone where Helium is doubly ionized. Towards the inner parts, temperature rises and now Helium is completely ionized. By the increase in pressure and temperature, the absorption of radiation within this zone increases, too. This additional energy has a damping effect. This expansion persist the general evolutionary process maintains the dimensions and properties of the excitation zone within the star.

Also by my comparisons I see that in instability region the stars pulsate neither than others. Because Deneb, Betelgeuse and X CYG are supergiants and nearly have same masses. Deneb is now behind the Cepheid Belt and we see that Betelgeuse passed this belt. But their brightness does not change. They do not pulsate, they are stable stars. When we observe X CYG, we can see that its brightness is changing because it is in instability region. After it finishes passing, it will be stable, too.

Another reason of the pulsation of the supergiants is The Kappa Mechanism. In that time of supergiants' life, they show us high temperature and pressure characteristics. So during that time because of the high energy the removing of materials from star is also have a damping effect in constant zones of the star, too.

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SPECTRAL CLASSES (O, B, A, F, G, K, M)

Type O Ex : Iota Orionis	Degree : 55000°F (over) Color : blue-white (white) Spectrum character : Gases, strobgly ionized (continous spectra)
Type B Ex : Rigel, Spica	Degree : 36000 °F Color : blue-white (blue) Spectrum character : strong neutral helium
Type A Ex : Sirius, Vega	Degree : 20000 °F Color : blue Spectral character : Hydrogen predominant
Type F Ex : Procyon	Degree : 13500 °F Color : yellowish-white Spectral character : hydrogen decreasing, metals increasing
Type G Ex : Sun, Capella	Degree : 11000 °F Color : yellow Spectral character : metals prominent
Type K Ex : Arcturus, Aldebaran	Degree : 7500 °F Color : orange Spectral character : metals surposs hydrogen
Type M Ex : Betelgeuse, Autares	Degree : 5500 °F Color : red Spectral character : titanium oxide, violent light weal

DICTIONARY

Adiabatic :

1. taking place without loss or gain of heat.
2. a curve on a graph representing the changes in two characteristics of a system undergoing an adiabatic process.

Amplitude : Astronomy. the angular distance along the horizon measured from true east or west to the point of intersection of the vertical circle passing through a celestial body.

- “Bolometric” is the adj. form of “Bolometer” :

Bolometer is a sensitive instrument for measuring radiant energy by the increase in the resistance of an electrical conductor.

Compensate : to offset or counterbalance the effects of (a force, weight, movement etc.) so as to nullify the effects of an undesirable influence and produce equilibrium.

Compression :

1. Also called: compressure. the act of compressing or the condition of being compressed.
2. an increase in pressure of the charge in an engine or compressor obtained by reducing its volume.

Dissipation : unrestrained indulgence in physical pleasures.

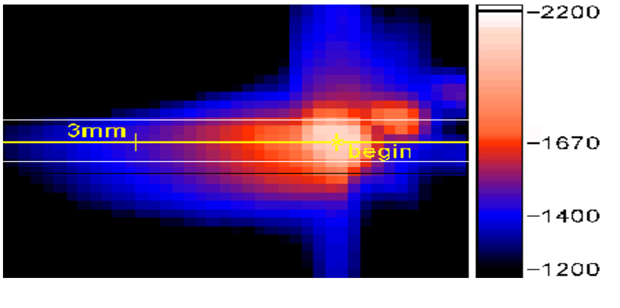
Doubly : to or in a double degree, quantity or measure.

Excitation : the current in a field coil of a generator, motor etc., or the magnetizing current in a transformer.

Flux :

1. continuous change; instability.
2. physics. a. the rate of flow of particals, energy or a fluid such as that of neutrons or of light energy. b. the strength of a field in a given area expressed as the product of the area and the component of the field strength at right angles to the area : magnetic flux; electric flux.

Fraction : chem. a component of a mixture seperated by a fractional process, such as fractional distillation. math. a. a ratio of two expressions ar numbers other than zero. b. any rational number that can be expressed as the ratio of two integers, a / b, where “b” does not equal “a”, 1 or 0 and “a” does not equal 0.



HOFMEISTER : His real job is botanic; But he also study the affect of gravity and the mechanic of flexibility.

Intimate : of or relating to the essential part or nature of something; intrinsic.

Overall :

1. From one end to to the other.
2. Including or covering everything

- Oscillating Universe Theory : the theory that the universe is oscillating between periods of expansion and contraction.

oscillation : physics, statistics. a. regular fluctuation in value, position, or state about a mean value, such as the variation in an alternating current or the regular swinging of a pendulum.
b. a single cycle of such a fluctuation.
Persist : to continue to exist or occur without interruption.

Preliminary :

1. occuring before or in preparation
2. a preliminary event or occurence
3. an eliminating contest held before the main competitien.

Tendency : an inclination, predisposition, propensity or leaning.

destabilize (destabilization) : to undermine or subvert so as to cause unrest or collapse.

stabilize (stabilization) :

1. to make or become stable or more stable.
2. to keep or be kept stable.
3. to put or keep in equilibrium by one or more special devices or to become stable.

ABSTRACT

My project started with a question, “Why supergiants pulsate in instability region neither than others?”

First of all, I searched about AAVSO (The American Association of Variable Star observers) Because it was investigating Variable Stars and I needed information about it. The reason of this: supergiants that are pulsate in instability region neither than others, are also Cepheids which are the one type of Variable Stars.

After I learned more about AAVSO, I searched Cepheid Variable, too. To show the difference between these supergiants, I also wrote, how the evolution of a Sun-Like (dwarf) star and supergiant

In the 3rd step, I gave more detailed information about massive (supergiant) stars and information about Hertzsprung-Russell Diagram. Because I can get lots of evolutionary information of a star from the H-R diagram, too.

After all of these steps, I learned the informations that I have to know and then I started to find out my answer. I gave the reasons of some “supergiants’ pulsation in instability region” process in detail. I wrote about the origin of pulsation, evolutionary state, why do some stars pulsate and a related topic to these Causes of the changes in brightness.

Through the end, to proof my foundings more visually and to give an example with stars, I wrote about my observations. I gave the informations about the techniques that I use and the chosen stars.

In the conclusion part, I gave the answer of my question and I told about the benefits of my observations. As a summary, the origin of pulsation is; because of the high temperature and pressure, helium atoms are totally ionized and that’s why there were some defective effects in star’s radiation, we see as it pulsates. Also the Kappa Mechanism is effeting to its pulsation, too.After conclusion part, I wrote my sources that are very helpful for me and I especially used the one which are easy to understand for my grade.

At last I made a dictionary part. I t was very useful for me. Because the words that are in there, I did not know them either at the beginning. I think, the dictionary part will be useful for my readers, too.