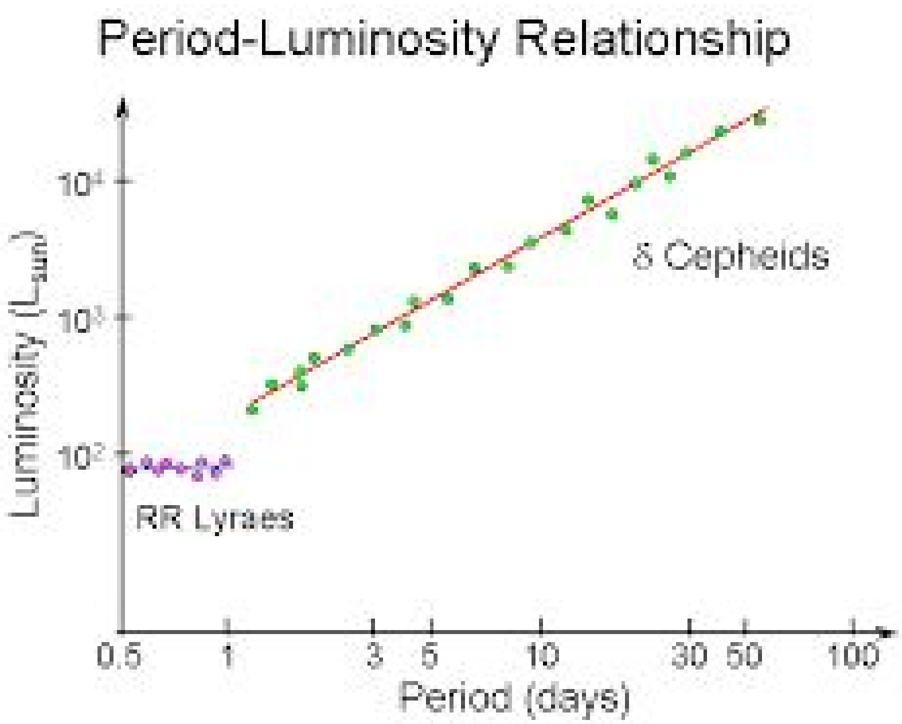
Instability Strip

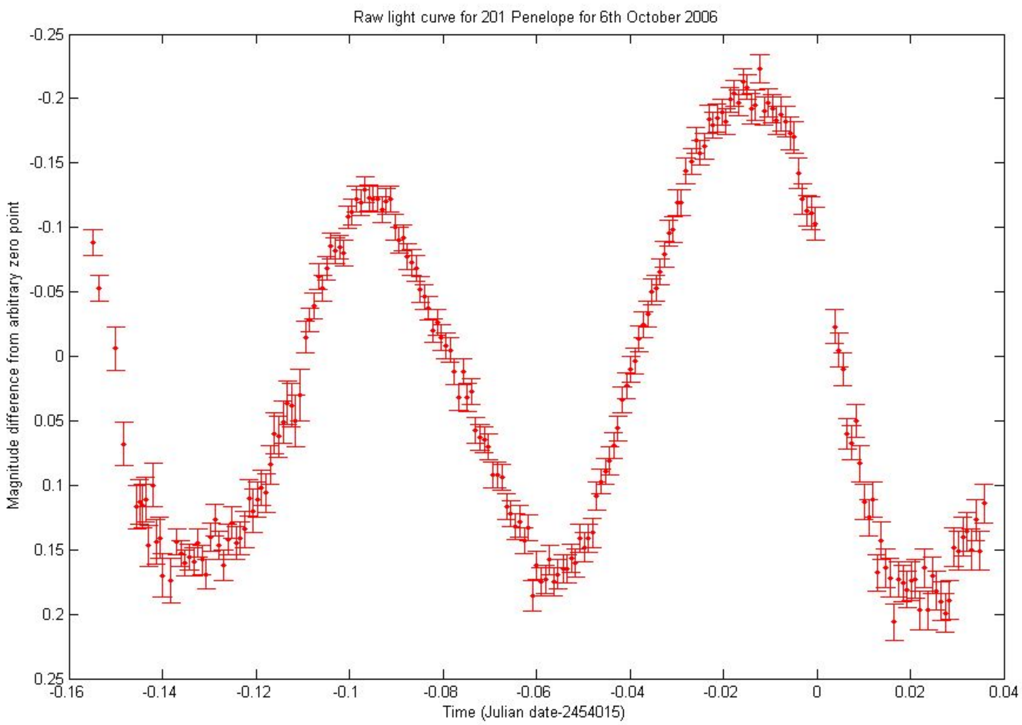
On the H-R diagram, there is the main sequence which consists of the stars that are normal and have a size that corresponds to its temperature. This means that stars that appear on the main sequence have hydrostatic equilibrium, or the gravity pushing in is the same as the pressure pushing outwards. Perpendicular to the main sequence is the instability strip which holds the stars that are not stable or vary in temperature. They usually contain pulsating variable stars such as RR Lyrae, Cepheid variable, W Virginis, and ZZ Ceti stars. When a star finishes with hydrogen fusion and completes its time on the main sequence, it starts to make its way to become a red giant or supergiant. During this process, the transition is not as smooth due to the various amounts of reactions that are occurring inside the star. This causes the stars to pulsate rapidly during this period. There is a relationship between how large or bright the star is and how long it takes for the star to pulsate as shown below. The larger the star, the longer it will take to pulsate, and the light/dim stars will pulsate more quickly. The period is the amount of time a star takes to go from maximum magnitude to minimum magnitude and then back again to maximum magnitude.



(Low mass stars become RR Lyrae variables and have the pulsation period of 1-3 days, medium mass stars become Type 2 Cepheids and have a pulsation period of 1-30 days, and heavy mass stars become Type 1 Cepheids and have a period of 30-100 days.)

While the star is pulsating, what happens inside of the star is that the radiation gets partially trapped, and the pressure increases because of this. Due to the pressure increase, it overcomes the star's gravitational pull and causes the star to expand a significant amount. After this, the expansion of the star allows for the radiation that is trapped to escape, decreasing the pressure in the star and cooling it. This causes the gravity to compress the star back to its normal size. The expansion and deflation of the star are also caused by the ionization of the helium atoms. The traditional helium has its nucleus consisting of 2 protons, 2 neutrons, and 2 electrons on the outside. When the star gets hotter, the helium gets ionized and loses an electron, and then if it gets even hotter, it gets doubly ionized and loses the second electron. Once both electrons are gone, it becomes more opaque and absorbs a lot of light. This makes the star extremely dim and extremely absorbent of light. Due to this, the star gets heated a lot and as stated before, causes the star to expand. Because the star expanded, the outer layers of the star become a lot cooler. This causes all the helium in the star to become singly ionized again. When it gets to this state, the star becomes more transparent, less opaque, and a lot brighter. At this stage, since it has expanded quite a bit, the star is not going to get heated as much causing the helium atoms to doubly ionize again, and this cycle continues on and on until the star once again reaches a stable point. Each time the cycle happens, the star loses some energy which eventually results in damping of the pulsations.

Cepheid variable stars are stars that have extremely high luminosity and are located on the long part of the horizontal instability strip. Massive stars become them when they are transitioning from the stable main sequence branch to the giant and supergiant branches. RR Lyrae variables are really old white giants that have low metallicity. Their periods usually only last from 4 hours to 1.2 days. On the H-R diagram, they are located near the horizontal giant branch and main sequence. Long Period Variables are red giants or supergiants that are pulsating stars. Their periods range from 30-1000 days as they are much larger. Mira variables are red giant stars that are pulsating about every 80-1000 days. These stars are usually medium mass and are transitioning to the red giant branch. On the H-R diagram, they appear between the medium mass stars on the main sequence and the red giant branch. And finally, Semiregular variables are giants and supergiant stars with periods ranging from 30-1000 days. The period of all these pulsating stars can be determined by creating a light curve. A light curve is a plot that measures the change in the brightness of a star over time. They plot apparent magnitude (what we see) over time. These plots are usually measured in Julian Day (JD) where day 1 starts on January 1, 4713 BC. (Below is an example of a light curve).



Stars that fall on the instability strip can also be used to find how far a galaxy is from us. To do this, you have to measure its pulsating period which will tell how massive and bright the star is (absolute luminosity). Then we can measure the apparent luminosity, or how bright the star appears to be, and using the formula: Apparent Luminosity = Absolute Luminosity/d^2, you can find the distance of the star.

While the location of many of these pulsating stars is scattered on the H-R diagram, they all share similar properties. For the purpose of this project, plotting these pulsating stars can be confusing when analyzing our data. Because their brightness and size can change from day to day, it may lead to false conclusions. Since we know the general location of where these stars are located, we can specifically take out stars that fall in those areas.

As seen below, the instability strip is the dotted black box area. It runs perpendicular to the main sequence and can extend all the way down to the white dwarf's area. The different types of variable stars are also labeled in this picture.