High Velocity Stars

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COSMOS: Cluster 9 Introduction to Astrophysics

July 24, 2009

Abstract

Much can be learned about High Velocity stars such as Barnard's Star through studying spectra taken of them. Spectra can reveal their composition, movement, speed, temperature and age which can be used to learn more about these stars. I have included one picture of Barnard's Star taken with a 10in Takahashi telescope. It was made from six 30 second exposures taken with a clear filter. Barnard's Star is the fourth closest star to our Sun but not visible with the naked eye. It has a total speed of about 140 km/s relative to our Sun. It also has a very large proper motion as it travels 10.3 arc seconds per year. Through studying motion and composition we can learn about the stars themselves and how our galaxy started.

High Velocity Stars

Our galaxy, the Milky Way, is in the shape of a disk, and because of this it is thought that it is a spiral galaxy (Smith, 1999). The stars in the galaxy are found in three different groups; the Galactic Bulge, the Galactic Disk and the Galactic Halo. The bulge is a dense spherical distribution of stars at the center of the galaxy, the disk is flat and is where most stars, including our Sun, are located, and the halo is a spherical group of stars surrounding our galaxy. The disk contains arms spread out in the shape of a spiral. There are four major arms with two minor ones extending near them (Milky Way). Stars in the halo are very spread out in comparison to stars in the disk and the bulge. The halo also contains many globular clusters, which are spherical collections of stars that orbit a galactic core. Beers et al.'s (2007) research has shown that the Galactic Halo is compromised of two separate groups. One travels at about 289681200 km/sec same direction as the Milky Way, while the other travels at 5793624000 km/sec in the opposite direction. It is also believed that some outer halo stars are stars that were once part of another galaxy and were absorbed into the Milky Way. This could explain their opposite movement and possibly why they are of different composition. The stars in the Milky Way can also be characterized by age: Population I and Population II stars (Strobel 2007). Population II stars are older and generally in the halo, while the Population I stars are generally in the disk of the galaxy. The bulge stars are older than the ones in the disk but younger than those in the halo.

My research covers High Velocity Stars. High Velocity Stars do not move faster than the rest of the galaxy, but they are moving fast from the Sun's perspective. Most stars close to the Sun appear to be moving slowly because they are moving together with our Sun. This is because the Sun and most of the stars around it are part of the disk. Halo stars that are near us move very quickly because they are not part of the disk so their relative motion is very high. These “High Velocity Stars” also happen to be metal-poor stars compared to the Disk Stars (Barnes 1997). When speaking of stars, any element that is heavier than helium is considered a metal. Stars that have higher amounts of heavier elements are said to have high metallicity. While Disk stars have close to 2% metallicity, these Halo stars have about 0.1% metallicity.

One way to study these stars is by taking their spectrum. All the different light that stars give off can be organized in the Electromagnetic Spectrum. When a star’s spectra is taken with a spectrograph, the amount of light that star is giving off in each wavelength is counted and recorded. Through taking and studying the spectra of these high velocity stars, we can learn many things that can show us why they are different than the disk stars or even the inner halo stars. Spectra can reveal movement through the Doppler shift of light (Figure 1). Each element in the periodic table has certain wavelength measurement patterns that are found from light passing through it. An absorption spectrum is created when light is absorbed by elements and their electrons move up to a higher level of energy absorbing light at that certain wavelength. An emission spectrum shows when elements give off light from their electrons going down to a lower level. A Doppler Shift can be found in a spectrum by finding the exact wavelength patterns of certain elements that are moved either toward the red side of the spectrum or the blue side. Figure 2 shows what both a red shift and blue shift look like when seen on a spectrum. If a spectrum is “red shifted”, it means that the galactic object is moving away your position. If a spectrum is “blue shifted”, it means that the galactic object is moving towards you. A Doppler shift is caused because when an object is moving closer to you or farther from you the wavelengths it causes are made either longer or shorter. Figure 1 which shows how wavelengths can change when an object is moving. The change in length causes the lines to on the electromagnetic spectrum. Upon studying the Doppler shift of certain stars, we can also learn how fast they are moving through the following formula: $v/c = \Delta\lambda/\lambda$, where v is the radial speed of the object, c is the speed of light, $\Delta\lambda$ is the shift in wavelength and λ is the true wavelength. From certain patterns in a star's spectra, we may also learn their composition such as metallicity.

One example of a high velocity star is a red dwarf named Barnard’s Star. It is somewhere between 10 and 12 Billion years old (Solstation.com), which is considerably older than our Sun. It is an inactive red dwarf with a rotational period of 130 days (Solstation.com). The star is about 6 light years away from our Sun and has an absolute magnitude of 13.2 (Solstation.com). It is located in the northern part of the constellation Ophiuchus. Barnard’s Star is the fourth closest star to our Sun, but it is not visible to the naked eye because it only has an apparent magnitude of 9.57 (Solstation.com) and the naked eye can only see apparent magnitude of 6. This star has metallicity higher than that of Halo stars but lower than disk stars so it is considered an “Intermediate Population II Star”, but it is still a Halo star because of its velocity (Solstation.com). Barnard’s Star has less than 17% of our Sun’s mass and only about 15% of its diameter (Solstation.com). With respect to our Sun, it is thought to be moving with a total speed close to 140 km/sec (Solstation.com).

Data

The data consist of six 30 second exposures of Barnard’s Star taken on the roof of the Physics Geology building in the University California Davis Campus. The exposures were obtained on Monday July 20, 2009 with a 10in Takahashi telescope with a clear filter to get all visible light. The camera temperature was -9.78 C degrees. All the data reduction was conducted with the CCD Soft package. I began by combining the darks that were taken with the pictures of

Bernard's star into one image that I called the "Master Dark". I used the CCD soft to reduce the "Master Dark" from the folder of raw pictures of Bernard's Star. Then I aligned the folder of subtracted images and saved these new images into a new folder and used a median combine to make this folder into a single image of the star (Figure 3).

Analysis

My image shows Bernard's Star, which is a magnitude 9.57 star. We were unable to take a spectrum of Barnard's Star because with a spectrograph the light is spread out over many pixels while in an image the light is concentrated into only a few pixels. To get a spectrum of Barnard's Star would require either a larger telescope or to expose for a much longer time then was available. Barnard's Star has a proper motion, which is movement we can see in the sky, of 10.3 arc seconds per year (Solstation.com). This is the largest proper motion of any star in the sky. This great apparent movement is due to the fact that it is very close to our Sun. Using the distance of Barnard's Star and its proper motion, I have calculated that it has a tangential speed of about 87 km/sec. It is also known through Doppler shift measurements that Barnard's star has a radial speed of about 106 km/s (Wikipedia). Using the tangential and radial speed, I have calculated that Barnard's Star has a total speed of about 137 km/s relative to the Sun. Through proper motion and Doppler shift we can the true three dimensional velocities of stars. Although this is very useful, it does not work for all stars because most stars are so far away that we cannot see their proper motion.

Conclusion

Through studying the motion and composition of stars in our galaxy we can get clues as to how our galaxy was started. Through studying metallicity and other composition of stars, we can learn when these stars were “born”. If a star has very low metallicity we know that it is an older star and was “born” when the gas in the galaxy were less polluted by heavier elements. If we know the age of all the stars in our galaxy, we can then estimate how old our galaxy is. Through movement of stars we can learn how the stars are spread out through the galaxy. We know that halo stars are older because of their composition and can study them in groups separately from disk stars which we know are younger than halo stars.

Acknowledgements

We thank the U.C Davis COSMOS program for providing the opportunity to explore astrophysics.

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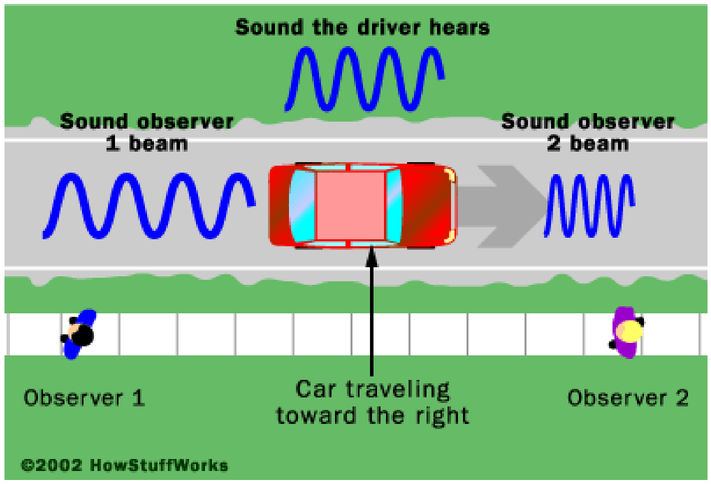

Figure 1: Sound affected by the Doppler shift.

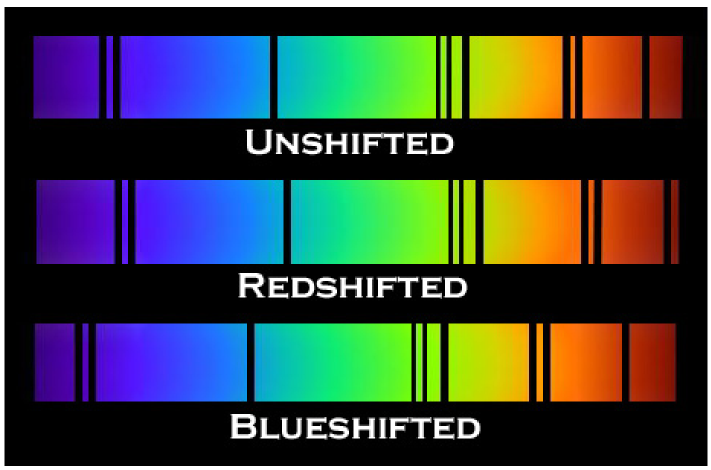

Figure 2: An example of red shift and blue shift.

Figure 3: Barnard’s Star