Researching Variable Stars and the Difficulties of Finding Them

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Overview

Variable stars are celestial objects that exhibit changes in their brightness over time due to internal physical processes or external influences such as interactions with other stars or planets. The study of variable stars is essential in understanding the evolution and dynamics of stars, galaxies, and the universe as a whole. Throughout this capstone, I researched variable stars and the observational techniques and theoretical models used to study variable stars. In supplement to this, I worked with Professor Bischoff to get the telescope in Braunstein in working condition so that we could collect data on variable stars. Unfortunately, we were unable to get the telescope to work successfully for data-taking purposes.

Variable stars have been a fascinating subject of study for astronomers since the invention of the telescope. These objects exhibit changes in their brightness over time, making them ideal candidates for studying the internal physical processes that govern the behavior of stars. Moreover, the study of variable stars has contributed significantly to our understanding of the universe's age, composition, and evolution.

Observational Techniques

Observing variable stars requires specialized techniques and instruments capable of measuring the changes in their brightness accurately. One of the most commonly used techniques is photometry, which involves measuring the amount of light emitted by a star and its variations over time. Astronomers use telescopes and cameras equipped with filters that allow specific wavelengths of light to pass through and then measure the amount of light received by the camera. Another popular technique is spectroscopy, which involves analyzing the spectra of the star's emitted light to determine its chemical composition and physical properties. Spectroscopy is particularly useful in studying pulsating variable stars, such as Cepheid variables, which exhibit periodic variations in their spectral lines.

In addition to photometry and spectroscopy, astronomers also use other observational techniques to study variable stars. For example, interferometry is a technique that involves combining the light from multiple telescopes to produce a high-resolution image of the star's surface. This technique allows astronomers to study the star's physical properties, such as its size, temperature, and surface features. Polarimetry, which involves measuring the polarization of the star's light, is also used to study variable stars. Polarimetry can provide valuable information about the star's magnetic field and the orientation of its axis of rotation. The study of variable stars requires a range of observational techniques and instruments, each with its strengths and limitations. By using these techniques, astronomers can gain valuable insights into the behavior and properties of these fascinating celestial objects.

Theoretical Models

The study of variable stars also involves developing theoretical models to explain the physical processes that govern their behavior. One of the most important theoretical models in the field of variable star research is the pulsation theory, which explains the variations in brightness observed in many types of variable stars. Pulsation theory proposes that the variations in brightness are due to the expansion and contraction of the star's surface caused by changes in its internal temperature and pressure. Other theoretical models used to study variable stars include the hydrodynamic and radiative transfer models, which help to explain the physical processes that govern the star's energy production and transport (Russell et al., 2015).

Binary variable star systems, such as SS Cygni, are also an important area of study in the field of variable star research (Kimura et al., 2021). These systems consist of two stars orbiting around a common center of mass, and they can exhibit a range of variability patterns, including eclipsing and cataclysmic behavior. Theoretical models have been developed to explain the physical processes that govern the behavior of binary variable stars. For example, the Roche model is a widely used theoretical framework that describes the structure and dynamics of close binary systems (Sluys, 2006). The model takes into account the gravitational interaction between the stars and predicts their shapes, the transfer of mass between the stars, and the conditions for accretion disk formation. In addition to the Roche model, other theoretical models are also used to study the behavior of binary variable stars. For instance, the disk instability model is used to explain the outburst behavior observed in cataclysmic variable stars, such as SS Cygni. According to this model, the outbursts are caused by the accumulation of material in an accretion disk around one of the stars, which eventually becomes unstable and releases a burst of energy. SS Cygni is believed to operate exactly as following the disk instability model where the white dwarf star pulls mass from the red dwarf star into its accretion disk (aavso, 2023). The study of binary variable stars involves developing theoretical models to explain their complex behavior, including this interaction. These models are essential to understanding the physical processes that govern the behavior of these fascinating objects and to advancing our knowledge of the universe.

Significant Contributions

The study of variable stars has led to significant discoveries and contributions to our understanding of the universe. For example, the period-luminosity relation discovered in Cepheid variables by Henrietta Swan Leavitt in the early 20th century has been instrumental in determining the distance to remote galaxies and establishing the scale of the universe (SDSS, 2019). This discovery has been described as providing the first "standard candle," which is a celestial body with a known luminosity, on the cosmic distance ladder. The discovery of the first exoplanet orbiting a pulsating variable star, PSR B1257+12, in 1992, was another significant contribution to the field (Wolszczan, 2005). This discovery opened up new avenues of research into the study of exoplanets and their interactions with variable stars.

In addition to these significant contributions, the study of variable stars has also led to a better understanding of the processes that govern the evolution and behavior of stars. For instance, observations of eclipsing binary stars have provided insights into the fundamental parameters of stars, such as their masses and radii. Variable stars have also been used to study the history and evolution of the Milky Way galaxy. By observing the properties and distribution of different types of variable stars, astronomers can reconstruct the history of star formation and the dynamics of the galaxy. Furthermore, the study of cataclysmic variable stars has led to insights into the physics of accretion and the production of X-rays in these systems (Russell et al., 2015).

The study of variable stars is essential to our understanding of the physical processes that govern the behavior and evolution of stars. By observing and modeling the variations in brightness and spectral characteristics of these objects, astronomers can gain insights into the complex interplay between the physical conditions inside stars and the transfer of energy and matter through their outer layers. Moreover, the study of variable stars is critical to advancing our knowledge of fundamental physics, including the behavior of matter under extreme conditions and the properties of exotic objects such as neutron stars and black holes. As we continue to develop new observational and theoretical techniques for studying variable stars, we will undoubtedly uncover new and exciting phenomena that challenge our current understanding of the universe.

Finding Variable Stars

Our initial variable star target to view was SS Cygni due to its extensive following of amateur astronomers that have provided a surplus of data on SS Cygni's cycle of variability and its changes in luminosity. It's prone to being an especially ideal target due to the fact that it is nearly circumpolar and the presence of several comparison stars amongst its place in the night sky. However, coupled with the difficulty of figuring out how to set up and calibrate the Meade LX200GPS, we were unable to observe SS Cygni early enough in the season. SS Cygni's azimuth tended to follow nearly that of the sun's, which made night-time viewing impossible. Other possible night-time targets that we had found at this point included Algol and Lambda Tauri, which are ecliptic variable stars, Delta Cephei and Zeta Geminorum, which are cepheid variable stars, and Mu Geminorum, which is another dwarf novae. These stars all seemed to be at an acceptable azimuth for night-time viewing with a significant difference in luminosity while remaining bright enough to see using the Meade LX200GPS telescope.

Although we had overcome the initial difficulty of being unable to view our preferred variable star, we had not successfully figured out how to use the telescope. Our process of using the telescope is as follows:

1. Remove the lens cap from the telescope and the spotter's scope.

2. Unlatch the shutter of the slit in the dome.

3. Using the control panel, raise the shutter to a sufficient height to ensure that it is fully clear of the telescope's path.

4. Use the rotating ring to rotate the dome until the slit is in the direction of desired viewing. During the initial setup of the telescope, the direction of the desired viewing was toward the north in order to calibrate the telescope using Polaris.

5. Turn on the telescope and then use the AutoStar II Hand Controller, or the paddle, in order to initiate the setup process of the telescope. This included inputting the correct date and time and selecting a calibration process.

Initially, we were using the one-star alignment option which simply had us calibrate the telescope by using Polaris. After the telescope had been aligned using the one-star alignment, however, it seemed to be unable to correctly find another star that had been among the options of the paddle for preselected observation targets. Changing the observation target did not seem to resolve the issue, so we proceeded with a two-star alignment process. After aligning the telescope with Polaris, we then manually aligned the telescope with another preselected observation target on the paddle and then tested this alignment with a third star with no indication of success. At one point, we were able to get the telescope to automatically focus on what seemed to be the correct star using the preselected observation targets, but after attempting to recreate this process in order to understand the success of the calibration, we were unable to replicate its success and spent the subsequent attempts of the night failing to understand the initial success of the calibration.

We were unable to conclusively decide on the issue for the calibration process, but it seemed that Stellarium was successfully connected to the telescope although it disagreed on where the telescope was looking. This seems to be an indication that the GPS in the telescope was possibly dead, bugged, or had outdated firmware. An update of the telescope's firmware was successfully carried out with no indication of a difference in the calibration process's success. There were also issues of knowing which direction was true north because of labels on the walls of the dome that indicated the cardinal directions. These labels were taken as fact, however upon further scrutiny, they seemed to be generalizations of the cardinal directions and skewed about 15 degrees from the true directions. Even after correcting for this and aligning the telescope further, there seemed to be no strides closer to success. Although there were several issues in the initialization of the telescope, the camera suggested that it was correctly connected to the telescope and the computer. We were even able to take images that appeared to show the motion of the night sky with second-long exposures displaying streaks in the images we took. Due to the difficulty in the calibration of the telescope, however, we were unable to discern exactly what celestial bodies we were looking at. Because of all of these technical difficulties, we were unable to collect any viable first-hand data on variable stars such that this capstone is for the purpose of discussing the research process and the journey of figuring out how to operate a telescope with the intention of collecting data on variable stars.

Conclusion

The study of variable stars is essential in understanding the dynamics and evolution of stars, galaxies, and the universe as a whole. Observational techniques, such as photometry and spectroscopy, are used to measure the changes in the star's brightness, while theoretical models, such as pulsation theory, explain the physical processes that govern their behavior. The significant contributions made in the field of variable star research have led to groundbreaking discoveries and advancements in our understanding of the universe. Although the attempts to collect first-hand data of variable stars and differences in their luminosities failed due to technical difficulties, this experience has been very informative and was successful in teaching me more about variable stars and operating visible light telescopes.

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