INNOVARE JOURNAL OF SCIENCES
Vol 8, Special Issue 1, 2020
INNOVARE ACADEMIC SCIENCES
Knowledge to Innovation
ISSN-2321-5496

Full Proceeding Paper

AN INTRODUCTION TO VARIABLE STARS IN ASTRONOMY

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Received: 25 January 2020, Revised and Accepted: 17 March 2020

ABSTRACT

Objective: The Variable Star (brightness changes) of these stars can range from a thousandth of a magnitude to as much as twenty magnitudes over periods of a fraction of a second to years, depending on the type of variable star. Over 150,000 variable stars are known and catalogued, and many thousands more are suspected to be variable. There are a number of reasons why variable stars change their brightness. Some variable stars are actually extremely close pairs of stars, exchanging mass as one star strips the atmosphere from the other. Variable stars are classified as either intrinsic, wherein variability is caused by physical changes such as pulsation or eruption in the star or stellar system, or extrinsic, wherein variability is caused by the eclipse of one star by another, the transit of an extrasolar planet, or by the effects of stellar rotation.

Methods: We can choose a 'model' of a given star by requiring that it reproduce the observed variability as well as the other observed characteristics of the star. From the model, we can then learn about the internal composition, structure, and physical processes in the star. Astronomers have studied all types of stars, on all time scales from milliseconds to centuries, in all regions of the spectrum.

Conclusion: Variable stars provide important information about astrophysical processes, about the nature and evolution of stars, and even about the size, age, and evolution of the universe. Variable star observation and analysis are inherently simple, but the actual techniques of analysis and interpretation involve a wide range of scientific and mathematical skill.

Keywords: - **:** stars; variable-stars, activity-stars: binaries-stars, chromospheres-stars,

INTRODUCTION

The study of variable stars is one of the most popular and dynamic areas of modern astronomical research. Variability provides us with additional parameters (time scales, amplitudes) which are not available for non-variable stars. These parameters can be used to deduce physical parameters of the stars (mass, radius, luminosity, rotation) or to compare with theoretical models. We can choose a 'model' of a given star by requiring that it reproduce the observed variability as well as the other observed characteristics of the star. From the model, we can then learn about the internal composition, structure, and physical processes in the star. The study of variability also allows us to directly observe changes in the stars: both the rapid and sometimes violent changes associated especially with stellar birth and death, and also the slow changes associated with normal stellar evolution. Even within the last few years, new types of variability have been discovered, usually (but not always) as a result of the development of new astronomical tools and techniques. Until astronomers have studied all types of stars, on all time scales from milliseconds to centuries, in all regions of the spectrum.

Stars Position

Stars seem fixed to the celestial sphere, as it appears to revolve around the earth in its daily motion. The position of a star is given by its declination and right ascension, which are analogous to latitude and longitude on earth. The declination is the angular distance of the star north or south of the celestial equator, which is the projection of the earth's equator on to the sky. The projections of the earth's axis of rotation on to the sky are the north and south celestial poles. The declination ranges from $+90^\circ$ to -90°, or 90°N to 90°S. The right ascension is measured eastward around the celestial equator from a reference point called the vernal equinox to the foot of the hour circle through the star. The vernal equinox is the point at which the sun crosses the celestial equator, moving from south to north, in its apparent annual motion around the sky. The hour circle is the circle that passes through the star and the celestial poles; it is analogous to a meridian on earth. The right ascension ranges from 0 to 24 hours, where one hour of angle corresponds to 15°. Depending on the latitude of the observer, the star may be observable throughout the year, or at certain times of the year, or not at all. The position of a star places it in one of the 88 constellations (the same as the number of keys on a piano). This leads to some of the classical ways of naming stars: the Bayer (Greek letter) names in which a Greek letter (usually in order of decreasing brightness) is combined with the genitive of the (Latin) constellation name; and the Flamsteed numbers in which a number, assigned to each of the brighter stars across a constellation in order of increasing right ascension, is combined with the genitive of the constellation name.

Binary and multiple stars

The majority of stars in our galaxy are in binary or multiple star systems; the sun is an exception in this regard. The nearest star, α Centauri, is actually a pair of sunlike stars in mutual orbit, with a third, fainter star, orbiting much farther away. The brightest star, Sirius, is a pair consisting of a normal star and a white dwarf -- a stellar corpse. And Lyrae is a pair of pairs. A binary star system is a pair of stars that are gravitationally bound, and move together through space. They move in orbit around their mutual centre of mass (or gravity). Their distance from the centre of mass is inversely proportional to their mass. A multiple star system is three or more stars, gravitationally bound, and moving together. Multiple star systems are arranged hierarchically: a close pair and a single star in mutual orbit; two close pairs in mutual orbit etc. A non-hierarchical arrangement would not be stable over long periods of time. Binary systems may enable us to measure the masses of the stars, and are therefore of great importance. In some binary systems, the stars are close enough to eclipse, or to interact so as to influence each other's behavior and evolution; these will be variable stars.

Types of Variables

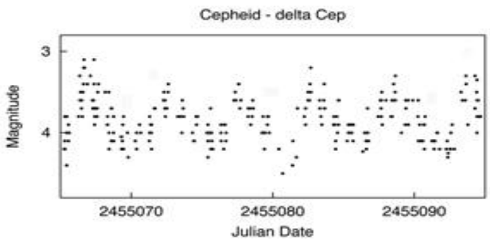
There are two kinds of variable stars: *intrinsic*, in which variation is due to physical changes in the star or stellar system, and *extrinsic*, in which variability is due to the eclipse of one star by another or the effect of stellar rotation. Variable stars are frequently divided into five main classes: the intrinsic pulsating, cataclysmic, and eruptive variables, and the extrinsic eclipsing binary and rotating stars.

Generally, long period and semi-regular pulsating variables are recommended for beginners to observe. These stars have a wide range of variation. Also, they are sufficiently numerous that many of them are found close to bright stars, which is very helpful when it comes to locating them.

PULSATING VARIABLES

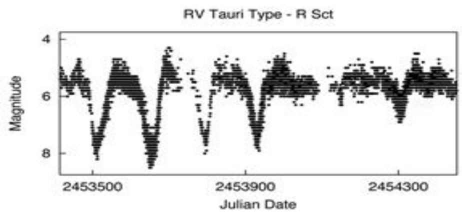
Pulsating variables are stars that show periodic expansion and contraction of their surface layers. Pulsations may be radial or non-radial. A radially pulsating star remains spherical in shape, while a star experiencing non-radial pulsations may deviate from a sphere periodically. The following types of pulsating variables may be distinguished by the pulsation period, the mass and evolutionary status of the star, and the characteristics of their pulsations.

Cepheids – Cepheid variables pulsate with periods from 1 to 70 days, with light variations from 0.1 to 2 magnitudes. These massive stars have high luminosity and are of F spectral class at maximum, and G to K at minimum. The later the spectral class of a Cepheid, the longer is its period. Cepheids obey the period-luminosity relationship. Cepheid variables may be good candidates for student projects because they are bright and have short periods.



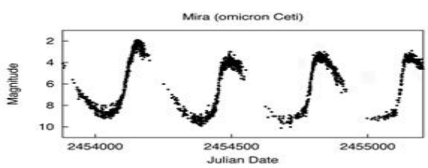
RR Lyrae stars – These are short-period (.05 to 1.2 days), pulsating, white giant stars, usually of spectral class A. They are older and less massive than Cepheids. The amplitude of variation of RR Lyrae stars is generally from 0.3 to 2 magnitudes.

RV Tauri stars – These are yellow supergiants having a characteristic light variation with alternating deep and shallow minima. Their periods, defined as the interval between two deep minima, range from 30 to 150 days. The light variation may be as much as 3 magnitudes. Some of these stars show long-term cyclic variations from hundreds to thousands of days. Generally, the spectral class ranges from G to K.

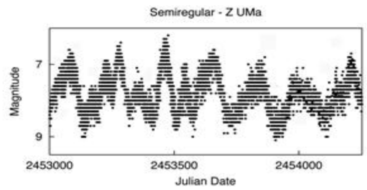


Long Period Variables– Long Period Variables (LPVs) are pulsating red giants or super-giants with periods ranging from 30-1000 days. They are usually of spectral type M, R, C or N. There are two subclasses; Mira and Semi-regular.

Mira – These periodic red giant variables vary with periods ranging from 80 to 1000 days and visual light variations of more than 2.5 magnitudes.



Semi-regular – These are giants and supergiants showing appreciable periodicity accompanied by intervals of semi-regular or irregular light variation. Their periods range from 30 to 1000 days, generally with amplitude variations of less than 2.5 magnitudes.

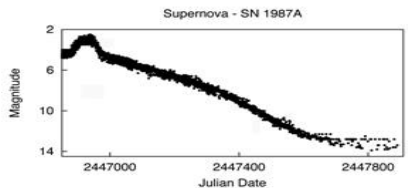


Irregular variables – These stars, which include the majority of red giants, are pulsating variables. As the name implies, these stars show luminosity changes with either no periodicity or with a very slight periodicity.

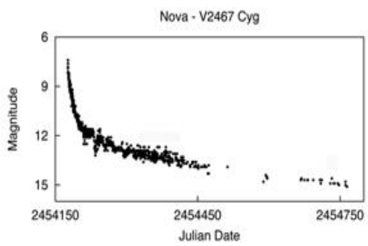
CATACLYSMIC VARIABLES

Cataclysmic variables as the name implies, are stars which have occasional violent outbursts caused by thermonuclear processes either in their surface layers or deep within their interiors. The majority of these variables are close binary systems, their components having strong mutual influence on the evolution of each star. It is often observed that the hot dwarf component of the system is surrounded by an accretion disk formed by matter lost by the other, cooler, and more extended component.

Supernovae – These massive stars show sudden, dramatic, and final magnitude increases of 20 magnitudes or more, as a result of a catastrophic stellar explosion.



Novae – These close binary systems consist of an accreting white dwarf as a primary and a low-mass main sequence star (a little cooler than the Sun) as the secondary star. Explosive nuclear burning of the surface of the white dwarf, from accumulated material from the secondary, causes the system to brighten 7 to 16 magnitudes in a matter of 1 to several hundred days. After the outburst, the star fades slowly to the initial brightness over several years or decades. Near maximum brightness, the spectrum is generally similar to that of A or F giant stars.



Recurrent Novae – These objects are similar to novae, but have two or more slightly smaller-amplitude outbursts during their recorded history.

Dwarf Novae – These are close binary systems made up of a red dwarf–a little cooler than our Sun, a white dwarf, and an accretion disk surrounding the white dwarf. The brightening by 2 to 6 magnitude is due to instability in the disk which forces the disk material to drain down (accrete) onto the white dwarf. There are three main subclasses of dwarf novae; U Gem, Z Cam, and SU UMa stars.

ERUPTIVEVARIABLES

Eruptive variables are stars varying in brightness because of violent processes and flares occurring in their chromospheres and coronae. The light changes are usually accompanied by shell events or mass outflow in the form of stellar winds of variable intensity and/or by interaction with the surrounding interstellar medium.

R Coronae Borealis – These rare, luminous, hydrogen-poor, carbon-rich, supergiants spend most of their time at maximum light, occasionally fading as much as nine magnitudes at irregular intervals. They then slowly recover to their maximum brightness after a few months to a year. Members of this group have F to K and R spectral types.

ECLIPSING BINARY STARS

These are binary systems of stars with an orbital plane lying near the line-of-sight of the observer. The components periodically eclipse one another, causing a decrease in the apparent brightness of the system as seen by the observer. The period of the eclipse, which coincides with the orbital period of the system, can range from minutes to years.

ROTATING STARS

Rotating stars show small changes in light that may be due to dark or bright spots, or patches on their stellar surfaces ("starspots"). Rotating stars are often binary systems.

CONCLUSION

Variable stars provide important information about astrophysical processes, about the nature and evolution of stars, and even about the size, age, and evolution of the universe. Variable star observation and analysis are inherently simple, but the actual techniques of analysis and interpretation involve a wide range of scientific and mathematical skill.

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