Variable stars

The high energy sources observed by INTEGRAL are often very variable at all wavelengths, including in visible light. The comparison of the light curves at different wavelengths provides important clues about the physical properties of the emitting sources, for example, its size and origin.

A star is considered variable if its apparent brightness (its brightness as seen by an observer on Earth) changes over time. There are many different types of variable stars which show different properties; Cepheid variables, RR Lyrae variables and eclipsing binaries are just a few examples. A star can vary in brightness for different reasons that are either 'intrinsic' or 'extrinsic'.

Intrinsic and Extrinsic variables

Variations to the brightness of an intrinsic variable star are caused by some change within the star itself, for example:

- An otherwise normal star can experience a flare. This is similar to the flares in the Sun, but on a much larger scale. In some cases the flares are induced by the accretion of material from a companion star. After the flare, the star slowly returns to its normal state of emission. Flares might be periodic in some stars, but usually they occur randomly.
- Some stars are unstable and pulsate rhythmically, becoming larger and smaller in a periodic manner. These pulsations translate into a periodic variation of the light they emit. The most well known stars of this kind are Cepheid variables that have very stable pulsation periods.

The changes in the observed brightness of an extrinsic variable star are either due to some process that is external to star or the rotation of the star, for example:

- Most of the stars in the Milky Way are thought to be in binary (or even multiple) star systems. A binary system is where two stars are orbiting around their common centre of gravity. If the plane of the orbit is close to the line of sight of an observer on Earth, eclipses will occur. The light emitted by the stars will therefore not be constant, but will show two minima: one when the primary star is in front of the secondary, and a second one when the secondary is in front of the primary. The rest of the time we see the light from both stars together, if they are close enough.
- In some cases, both stars are so close to each other that their period is very short, just a few hours. In the most extreme cases, both stars are so close together that their external atmospheres touch. The light curves of these eclipsing binaries are periodic, as a consequence of their periodic orbital motions. If a sufficient number of cycles are observed, the periods can be derived with accuracies of tiny fractions of a second.

About the variable stars you will observe

For the *Explore the high-energy Universe competition* observing project, students are challenged to observe a number of different types of variable stars. A list of target variable stars is provided (see Observing list document). These stars have been selected because they are all visible from the northern hemisphere during the period of the competition and can be observed using a small telescope. In addition, these variables have all been observed using the Optical Monitoring Camera, or OMC, onboard the INTEGRAL mission.

In the provided Observing list, the stars are referred to using an abbreviation depending on the type of variable they are. A short description of the different types of variable stars included in the Observing list is provided here.

Pulsating variable stars

For some variable stars, the brightness changes are due to change in the star's size as its outer layers expand and contract in a rhythmic manner. These stars are called pulsating variables because they periodically swell and shrink, as if they were breathing in and out. This pulsation causes periodic changes to the surface temperature, spectrum and brightness of these stars. There are different types of pulsating variable stars that are characterised by their different light curves.

Stars can pulsate at different stages of their (stellar) evolution. A region of the Hertzsprung-Russell diagram, known as the instability strip, identifies pulsating variable stars. The instability strip crosses the main sequence of bright, massive blue, white and yellow stars, which means that these types of stars become variable at some point in their evolution.

Pulsating variable type: Classical Cepheid or Delta Cephei-type

Observing list abbreviations: DCEP, DCEP(B), DCEPS

Classical Cepheid variables are highly luminous, yellow giant or supergiant stars that pulsate on a very regular basis. Some of them change in brightness very quickly, over a period of only one day, whereas others are characterised by slower changes and have periods of up to 70 days.

Their masses range between 4 and 20 times that of the Sun. Cepheid variables can be found in open clusters in the spiral arms of galaxies.

They are also known as Delta Cephei-type stars, after the star Delta Cephei, in the constellation of Cepheus, the King, which was one of the first variable stars observed.

DCEP(B): These are Delta Cephei variables that display the presence of two or more simultaneous pulsations. A guitar string has a fundamental tone that gives its pitch; it also vibrates at higher frequency overtones. In a similar way these types of pulsating variable stars usually have a fundamental tone with the period P0 and the first-overtone, P1.

DCEPS: These are Delta Cephei variables that have almost symmetrical light curves as a rule and their periods do not exceed 7 days. They are probably first-overtone pulsators and/or are in the first transition across the instability strip after leaving the main sequence (for example, SU Cas).

Pulsating variable type: RR Lyrae variables

Observing list abbreviation: RRAB

RR Lyrae variables are yellow or white giant stars that pulsate on a regular basis and are often found in globular clusters. Pulsating variable stars of this type are less massive and fainter than Cepheid variables; they are older, more evolved stars that have left the main-sequence phase of stellar evolution and are burning helium in their cores.

Rotating variable stars

Another class of variable stars owe their change in brightness to their irregular shape and/or to their non-uniform surface. In some cases, the star's shape may not be a perfect sphere, but rather an ellipsoid. Alternatively, the brightness across the surface of the star itself may vary because of temporarily brighter and darker patches on the star's surface, similar to sunspots on the Sun (in this case they are called starspots).

These stars are classed as rotating variables. The observed change in their apparent brightness is due to the rotation of the star. This means that brighter and dimmer areas come into view as the star turns (in the case of starspots) or different amounts of the star's surface area (in the case of stars that are not perfectly spherical).

Rotating variable star type: Ellipsoidal

Observing list abbreviation: ELL

These rotating variable stars fall into the category of stars that are not perfectly spherical in shape, but are an ellipsoidal. Ellipsoidal variables stars are often in a binary system where the two stars that are orbiting around one another are very close together. These binary stars are so close together that their mutual gravitational attraction distorts their shape.

Eclipsing variable stars

Stars in a binary system, where two stars are orbiting around one another, may appear to us as a variable star. This happens when the plane in which the stars are orbiting lies near the line-of-sight to an observer on Earth. This means that, to an observer on Earth, the stars appear to pass in front of, or eclipse, one another on a regular basis. When this happens the apparent brightness of the binary system decreases. These variable stars are classed as eclipsing variable stars.

Eclipsing binary variable star type: Beta Lyrae-type

Observing list abbreviation: EB

In this type of eclipsing binary system, the two stars are very close together. This means that the mutual gravitational attraction of the stars in the system distorts their shape so that they are not perfectly spherical but ellipsoidal). Sometimes the gravitational attraction of one star on the other is so intense that it accretes part of the companion's mass.

Periodically, one of the two stars eclipses the other, and vice versa, giving rise to very regular brightness variations. The period of the variation depends on the time the two stars need to orbit around one another. As these stars are always very close together, the periods are short (one to a few days). The orbital motion of the two stars in these systems is so smooth that it is almost impossible to tell when an eclipse begins or ends from the light curve.

They are named after the prototype star of this kind of variable, Beta Lyrae, also known as Sheliak, which is in the constellation of Lyra, the Harp.

Eclipsing binary variable star type: Algol-type (Beta Persei)

Observing list abbreviation: EA

Algol-type variables are binary systems where the constituent stars are further apart compared to Beta Lyrae variables, hence they are spherical in shape (or very slightly ellipsoidal). For this type of eclipsing binary it is possible to tell - from the light-curve - when the eclipse begins and ends. The two subsequent dips in brightness of these variables, observed when one star eclipses the other, are separated by periods of almost constant light.

The period of the variation depends on the time the two stars need to orbit around one another. As the stars in these systems are always very close together, the periods are short, usually a few days.

They are named after the prototype star of this kind, Beta Persei, also known as Algol, which is in the constellation Perseus.

Eclipsing binary variable star type: W Ursae Majoris-type

Observing list abbreviation: EW

The stars in this type of eclipsing binary system are orbiting so closely together that their surfaces are almost touching one another. Therefore their mutual gravitational attraction is so intense, that it distorts their shape so that they are not spherical but ellipsoidal, and causes matter to transfer from one to the other. W Ursae Majoris-type variables orbit one another with a very short period, less than 1 day. Like Beta Lyrae-type stars, they are also too close together to tell exactly, from the light curve, when an eclipse begins and ends.

Further classification of eclipsing variables

Eclipsing binary variable star systems are classified further according to the physical characteristics of their component stars. This further classification is included in the observing list where appropriate, for example, EB/DM, EA/SD or EW/KE. The classifications are described here.

DM: Detached main-sequence systems. These are binary systems where both components are main-sequence stars, they are well separated from one another and there is no mass transfer between the two.

KE: Contact systems of blue-white stars. These are binary systems where the component stars are so close to each other than their surfaces touch or join together.

SD: Semidetached systems. These are binary systems where the less massive of the two stars is blowing out part of its material. Under the gravitational attraction of the more massive component, this matter will soon be transferred from one star to the other.