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Variable Star Of The Month

October, 2001: Gamma Cassiopeiae

Gamma Cassiopeiae and the Be Stars

Father Angelo Secchi made many important contributions to the field of astronomy. In addition to developing a scheme for stellar spectral classification, Secchi also furthered the area of solar physics with his studies of solar prominences and his proposal of a gaseous solar core.

Between 1863 and 1867, before the introduction of photography, Father Angelo Secchi (1818-1878) carried out a remarkable study of the spectra of some 4000 stars, using a visual spectroscope on the telescope of the Collegio Romano -- the forerunner of today's Vatican Observatory. He noted the absorption-line (dark-line) spectra of the stars, and developed a classification scheme which eventually led to the modern-day "Harvard system": OBAFGKM, in order of decreasing temperature. He also noted, in a 1867 publication, that Gamma Cas showed emission in the hydrogen-beta (H-beta) absorption line. Thus began the mystery of the Be stars: B to indicate the temperature class, and e to indicate the emission lines.

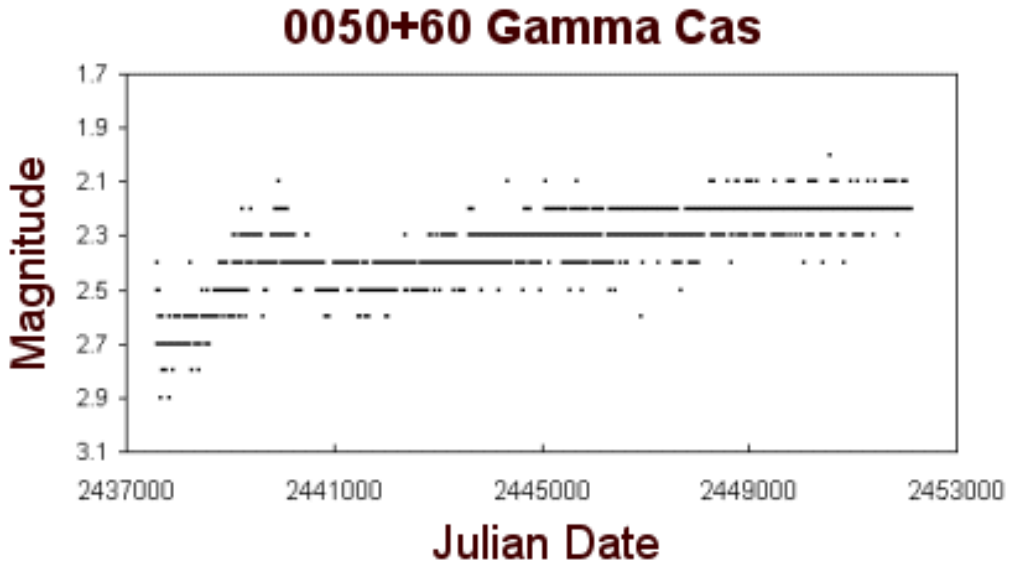
Be stars are now defined as non-supergiant stars with "surface" temperatures between 10,000 and 30,000 K, which have shown emission lines in their spectra on at least one occasion. About 20 percent of B stars are in fact Be stars. As the definition suggests, the spectra of Be stars can vary with time. The behavior of Gamma Cas over the years displays just this. From 1866 to 1942, Gamma Cas was relatively quiescent, with moderate to strong emission lines undergoing small variations from 1866 to 1932. This was followed by an episode of spectacular variations from 1932 to 1942, when the star became a rather normal B star! By 1981, it regained its irregularly-varying emission lines. Related to the Be stars are the shell stars: B stars with deep and narrow absorption lines in their spectra, superimposed on the normal broad absorption lines of hydrogen and helium which dominate their spectra. Stars can actually change from B to Be to B-shell and back to B again!

Very few astronomers monitor the changing spectra of Be stars, but this is something which is useful, and can be done by backyard observers with a small telescope and a spectrograph. Ernst Pollman in Germany, using a home-built spectrograph on a 20-cm telescope, has been particularly successful in this field. In a recent Be Star Newsletter (Pollman 2001), he reports observations of several stars including Gamma Cas: strong emission was seen around JD 2449800; then it declined steadily over the following 2300 days.

Gamma Cassiopeiae in the Visual

Gamma Cas also varies in visual brightness: between 1935 and 1940, for instance, it varied from 1.6 to 3.0 in V. As it is one of the stars which makes up the familiar pattern of Cassiopeia, these variations can significantly change the appearance of the constellation. The star is in both the AAVSO visual and the photoelectric photometry (PEP) programs, however, photoelectric photometry is recommended. This too is a challenge, because the extreme

brightness of the star makes it difficult to find suitable comparison stars nearby in the sky.



The AAVSO visual light curve of Gamma Cas from 1960 to present. Plotted are 10-day means. (Please note that there may appear to be horizontal lines in some parts of the light curve. These horizontal "lines" are in fact very dense concentrations of individual observations.)

Gamma Cas is a member of a visual double system (ADS782AB), and is also a member of a spectroscopic binary with a period of 203.59 days, an eccentricity of 0.26, and a companion with about the same mass as the sun (Harmanec et al. 2000). The companion could be a normal star, but it could also be a white dwarf or neutron star. This could explain why Gamma Cas is also an X-ray source (MX0053+60): the gas from the Be star could be accreting onto a compact companion, releasing gravitational energy which is transformed into thermal energy, and thence into X-radiation.

Be Stars

What distinguishes Be stars from normal stars on or near the main sequence? One thing is their rapid rotation -- up to 450 km/sec at their equator. This reduces the effective gravity at the equator of the star. The strong radiation of B stars (they are thousands of times more luminous than the sun) produces a "stellar wind" which, in Be stars, is focussed into an equatorial disc. The shell stars are mostly Be stars in which we see the disc edge-on: gases in the disc produce the deep, narrow absorption lines. Be stars are also a major contributor to "galactic ecology" -- the process by which stars lose mass, which becomes part of the raw material from which new stars and planets form. With modern optical interferometers -- two or more telescopes which image an object simultaneously -- it is possible to "see" these discs. Another possible factor in "the Be phenomenon" may be a magnetic field, but no field has yet been observed in most Be stars. (Some excellent information and interferometric images of Gamma Cas and other Be stars can be found at: www.obs-nice.fr/stee/Bemodel.html.)

Be stars vary in brightness, and spectrum, on several different timescales. There are variations on time scales of weeks to decades, which are connected with the formation and dispersal of the disc. These variations may be cyclic in nature; according to one theory, this is due to a spiral wave which slowly circulates around the disc. There are variations on time scales of days to weeks which are often connected with the binary motion of some of these stars; one example -- CX Dra -- is described below. Finally, there are variations on time scales of 0.3 to 2 days, which are due to non-radial pulsation, or perhaps rotation. These variations, which

occur on or near the surface of the star, may be connected with the formation of the disc around the star. AAVSO photoelectric observations are used primarily to study the slow variations, but a few photoelectric photometrists have participated in intensive "campaigns" to study the rapid variations.

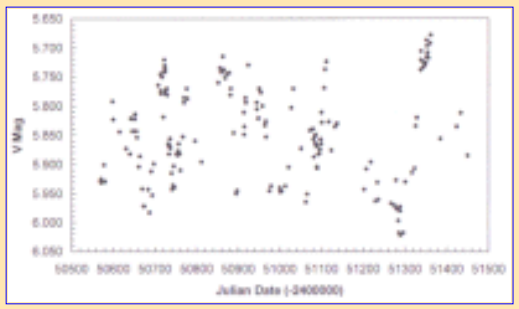
Recent Studies of Be Stars

An international long-term UBV photometry "campaign" on bright Be stars was established in 1980 by Petr Harmanec and some of his colleagues at the Ondrejov Observatory, Czech Academy of Sciences. This group, and another group of astronomers at Zagreb University in Croatia, share a 0.65m Cassegrain photometric telescope located on the island of Hvar, in Croatia. Due to the threat of military action in the region, observations were terminated in 1990; the mirrors were removed and hidden in a safe place. In the end, there was no damage on Hvar, and observations resumed in 1993. Some of the results of the photometry at Hvar have been published in an important paper by Pavlovski et al. (1997). Several Be stars were added to the AAVSO Photoelectric Photometry Program in support of this campaign (Percy, Desjardins, & Yeung 1996; Percy & Bakos 2001).

Hipparcos epoch photometry (1989-1993) has also been very useful in understanding the diverse behavior of a large sample of Be stars (Hubert & Floquet 1998). But the Hipparcos database still contains new clues to Be star behavior: high school student Ceci Pang, working with John Percy, recently found evidence for a 0.4-day period in Gamma Cas. The amplitude is only a few millimagnitudes.

Other Interesting Be Stars

CX Draconis is perhaps the most complex and interesting Be star on the AAVSO PEP program. This fifth-magnitude star brightens by about 0.2 magnitude, every few weeks (see figure to the right). It is a 6.696-day binary which has recently been studied intensively by Mercedes Richards and her collaborators (2000). The brightenings do not seem to be related to the binary motion, but there are small (0.02 magnitude) brightness variations which are correlated with the binary motion, and may be due to the distortion of one star by the other.

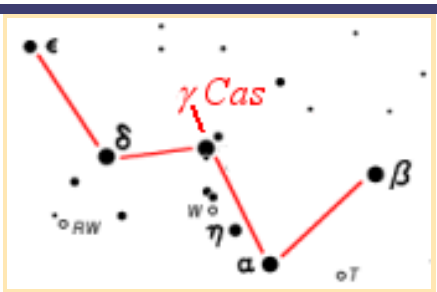


The V light curve of CX Dra, based on photometry from the AAVSO and from a robotic telescope. Note the brightenings every few weeks. (Click image to enlarge.)

Omicron Andromedae is an excellent example of short-period variability in a Be star: it has a period of 1.571272 days, with a variable amplitude of up to 0.1 magnitude. This variation was discovered by Paul Guthnick, one of the pioneers of photoelectric photometry, in 1918. AAVSO PEP observers are helping to monitor the changing amplitude of this rapid variability (Percy & Bakos 2001).

Observing Gamma Cassiopeiae and Friends

Gamma Cas is very easy to find, especially since it is one of the bright stars that forms the familiar "w"-shape pattern in the constellation of Cassiopeia. Although Gamma Cas is so bright that it may be seen by the unaided eye, its range of variation is relatively small -- based on the AAVSO International Database, it only varies by 0.6 magnitudes. Visual observers



Gamma Cas can be found as the middle peak in the "w"-shape formation in the constellation of Cassiopeia.

may certainly observe this variable star, but should be prepared to see only small-scale variations rather the larger-scale changes that can be seen in some of the other variable star types. PEP observers are encouraged to add Gamma Cas and other Be stars to their observing program, especially since these observing techniques are very useful for small-range variability. Being a bright star, CCD observers should probably refrain from observing Gamma Cas.

Any observer just starting out may wish to refer to the AAVSO Constellation Finder Chart for the field. This wide-field plot will help the new observer identify Gamma Cas' location in the sky and its relation to other nearby variables. Once comfortable with the field, observers can then move onto an AAVSO visual or PEP finder chart, depending on the observing method used, to make make brightness estimates of Gamma Cas.

Visual observers may use the 'a' scale chart of Rho Cas to observe Gamma Cas, which should be tracked once a week by visual means. When submitting data to the AAVSO, please report the decimal portion of the Julian Date to one decimal place. Also, be sure to indicate the chart(s) and the comparison stars used, and the equipment used in making the observation.

PEP observers may use the Gamma Cas PEP chart and should plan to observe the variable (and other variable stars of the same classification) every clear night, if possible. Because small scale-variations may be detected, PEP observers are asked to report the decimal portion of the Julian Date to 2 decimal places. PEP charts are also available for CX Dra and Omicron And -- both of these stars were mentioned above. Observers interested in participating in the AAVSO Photoelectric Photometry program should contact AAVSO Headquarters for more information.

The Future of Be Stars

Be stars remain a topic of intense scientific interest. What causes the formation and dispersal of a Be star's disc? What causes the short-term variability -- non-radial pulsation, or rotating structures in the inner disc? What is the role (if any) of binarity in Be stars? Although the proceedings of a recent IAU symposium (Smith et al. 2000) contains the "latest words" on the topic, AAVSO PEP observers are currently helping to address some of these questions (Percy & Bakos 2001).

For More Information

- *The Be Star Newsletter* (produced at Georgia State University for the IAU Working Group on Active B Stars): electronic version is hosted by the Limber Observatory: www.astro.virginia.edu/~dam3ma/benews/
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- Underhill, A.B. & Doazan, V. (editors), 1982, "B Stars with and without Emission Lines", NASA Special Publication SP-456. [Even after two decades, this is a comprehensive and useful resource on B and Be stars.]

This month's **Variable Star of the Month** *was prepared by Dr. John Percy, University of Toronto, editor of the AAVSO Photoelectric Photometry Newsletter.*

- Variable Star of the Month Archive