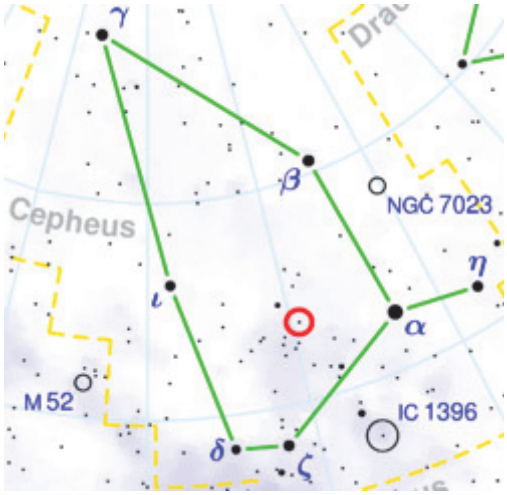
VV Cephei: an extraordinary binary system

VV Cephei eclipsing binary systems offer the most detailed method of studying mass loss from cool supergiant stars. The long-period of VV Cephei gives it a unique place among eclipsing binaries, but 20.4 years between eclipses make it really hard for scientists to study the system. Such a long interval gives only a couple of eclipse events in a working astronomical career for a human. Similar binaries are always good targets to follow, as the opportunity to obtain quality photometry and spectrometry of the eclipse is quite rare, but rewarding.

The system of *VV Cephei*, also known as *HD 208816*, has many features of exceptional interest. It is the prototype for a class of long-period eclipsing binary stars, with an M-type red supergiant as the primary and an early-type blue (usually B) supergiant or giant companion, and small variations in light. VV Cep is also an extra-ordinary example of a mass-exchanging eclipsing binary, in which a distorted, inflated red class M2 supergiant orbits a fainter, but much hotter, blue-white star. The pair orbits with a period of 20.4 years (7430 days, actually). The next eclipse is expected in 2017



Bright (4.9m) VV Cephei can be easily found even with a naked eye. It lays nearly halfway between Beta Cep and Delta Cep, close to the 4.3m spectroscopic binary Xi Cephei (SSE).

Averagely separated by 25 AU (a distance comparable to Neptune's orbit), a high eccentricity keeps them between 17 and 34 AU apart during the orbital cycle. When the blue star goes in back of the super-giant, the light drop from the binary during an eclipse is approximately 20% less than when both stars are fully visible.

The system of VV Cephei presents a rare opportunity to be studied as an astrometric, spectroscopic, and eclipsing binary. The spectral peculiarities and the variation of brightness of VV Cephei were discovered in the 1900s by Miss Cannon. Gaposhkin (1937) and Goedicke (1938) have presented data on the spectroscopic orbit and van de Kamp (1951) has given results of a provisional study of the astrometric material (Fredrick, 1960).

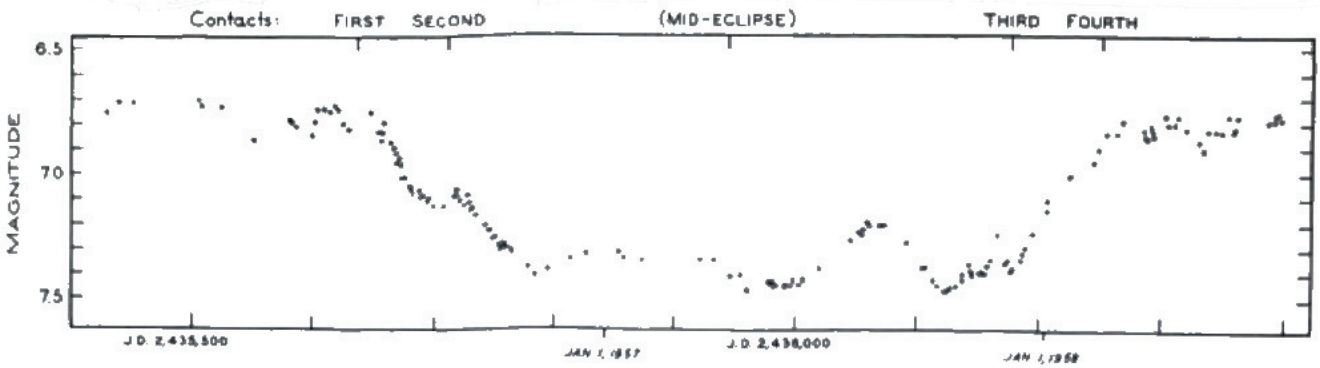
There is evidence of matter accretion from the primary star A onto the blue companion for at least part of the orbit. VV Cephei A (red) is not entirely spherical, being surrounded by a highly extended atmosphere. The red component has one of the biggest diameters ever measured at a star: the angular diameter can be estimated using photometric methods and has been calculated at 0.00638 arcseconds (Bennett, 2010). This allows a direct calculation of the actual diameter, which is in good agreement with the 1,050 solar radii derived by other methods. Analysis of the orbit and eclipses gives the possible size limit at 1,900 solar radii (Saito et al., 1980). Spectrum and the eclipses analysis gives radii for the supergiant between 1600 and 1900 solar (7.5 and 8.8 AU respectively).

The supergiant is so huge that the blue component is totally eclipsed for 250-300 days, a considerable part of the year. However, precise calculation of its diameter is a serious issue, as it seems to be distorted into a teardrop shape and fills its tidal surface. Due to mass accretion into a disk around the smaller and much hotter companion, the average diameter can be overestimated.

VV Cephei and its neighbourhood. Image credit: DSS2 All Sky Survey

Typical of supergiants, VV Cephei is also a pulsating semi-regular variable that changes by a few hundredths to a few tenths of a magnitude. The distance of the system from the Earth is usually estimated based on the known distance of other stars in the Cepheus OB2 association of stars, of which VV Cephei may be a member. But this is an open question whether VV Cephei has a physical connection with this group of stars or not.

Because of the long eclipse period, even less is known about VV Cephei B than about VV Cephei A. It seems to be unusually hot and dense for its type, and is probably no more than 10 times larger than the Sun. In a binary system, the evolutionary path of a massive star is drastically altered by the presence of a nearby companion due to mass-exchanging between them. The hydrogen emission disappears during the eclipse, therefore it originates in regions closely surrounding the B star (Goedicke, 1939).



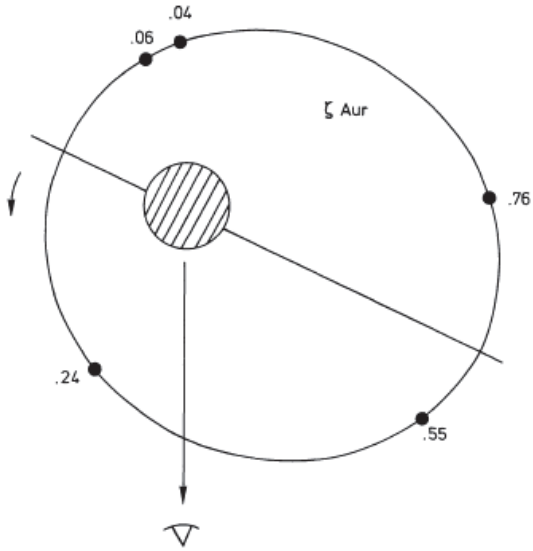
Historical light curve of VV Cephei during the eclipse of 1956-1958. Photoelectric measurements were made in blue light by G. Larsson-Leander. The light curve in the minimum is not flat, as might be expected, and shows waves due to intrinsic variations of the red supergiant component. The diagram was prepared by Laurence W. Fredrick and published in his article «World-wide observations of VV Cephei» (Sky & Telescope, January 1959, page 133)

The eclipse of 1976-1978 lasted about 1000 days of which the totality was about 300 days. More advanced hardware allowed to obtain very good samples of data in different bands. An in-depth analysis of the light curve during that eclipse is presented in the paper “Photometric study of VV Cephei during the 1976-78 eclipse” (Saito et al., 1980).

A good summary of “to-date” knowledge on 13 VV Cephei stars can be found in the historical paper by Anne P. Cowley (1969) - “The VV Cephei stars”. Despite the age, it's still a good source to read.

Zeta Aurigae (ζ Aur)

ζAur is another good sample of a long-period binary system, similar to VV Cephei, but with considerably shorter orbital period. Zeta Aurigae is an interacting eclipsing binary star 790 light years distant. It consists of a red K-type supergiant and a B8 type companion. The system’s magnitude varies between 3.61 and 3.99 with a period of 972 days. Because of more frequent eclipse events, the system can be observed seven times more than VV Cephei.



***Right**: Schematic view of highly-eccentric (e = 0.4) orbit of Zeta Aurigae, showing a relative position to the line of sight (Hempe, 1982).*

References for further reading:

- Goedicke, V. A., 1939; “The eclipsing binary VV Cephei”, The Observatory, 62, 197
- Fredrick, L.W., 1960; “The system of VV Cephei“, The Astr. Journal, 65, 628
- Gaposchkin, S., 1937, "The variable star VV Cephei as an eclipsing system", Harvard Coll. Circ., 421
- Kiyokawa, M., 1967; “Photoelectric observations of Zeta Aurigae during the 1963-64 eclipse”, Publ. Astron. Soc. Japan, 19, 209-219
- Saito, M., et al., 1980; “Photometric study of VV Cephei during the 1976-78 eclipse”, Publ. Astron. Soc. Japan, 32, 163-177
- Baldinelli, L., 1979; “Semiregular 58 Days Variation in VV Cep”, IBVS, 1675, 1
- Cowley, A. P., 1969; “The VV Cephei stars”, PASP, 81, 297
- Hempe, K., 1982; “A study of Ultraviolet spectra of ζAur/VV Cep Systems”, Astr. Astrophys., 115, 133
- Saitō, M., 1973; “An Expanding Circumstellar Cloud of Zeta Aurigae”, Astr. and Space Science, 22, 133
- Carpenter, K. G., 1992; “Zeta-Aurigae Type Binaries”, Proc.of the 151st. Symp. IAU, 151, 51
- Griffin, R. E. M., et al., 1990; “Optical spectra of Zeta Aurigae binary systems. I - The 1987 eclipse of Zeta Aurigae“, Astr. and Astrophys., 234, 284

Ivan Adamin