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Left: A Horseshoe Einstein Ring from Hubble.
Credit: ESA/ Hubble & NASA

SS Lacertae
the non-eclipsing eclipsing binary

The star is famous due to its extra-ordinary behavior, not typical of eclipsing systems: the complete cessation of eclipses in the middle of the twentieth century.

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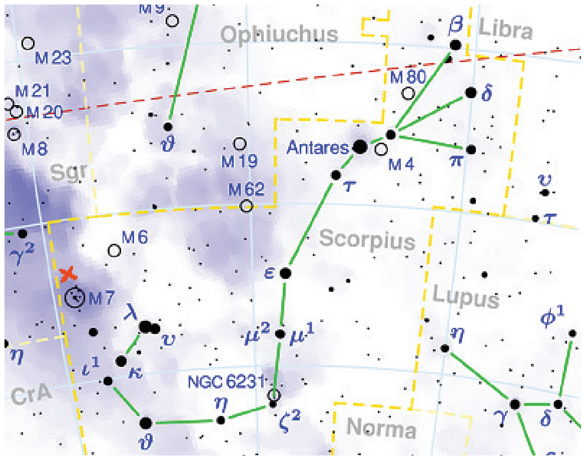

BL Boötis stars - anomalous Cepheids

These stars are similar to classical Cepheid variables, but they do not follow the same relationship between their period and luminosity.

RS Puppis:
the light echoes

RS Puppis is an unusual cepheid embedded into an dust cloud that is illuminated by the variable's light, enabling a phenomenon known as a light echo to be observed in details.

VS-COMPAS Research

A revision of NSV 13538 = NSVS 17231162

NSVS 11075037 = Dauban V53: a Mira variable in Hercules

Updated photometric elements of three variables in Lynx

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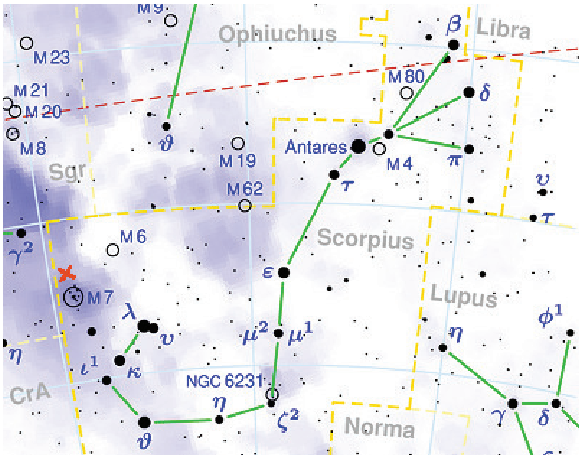


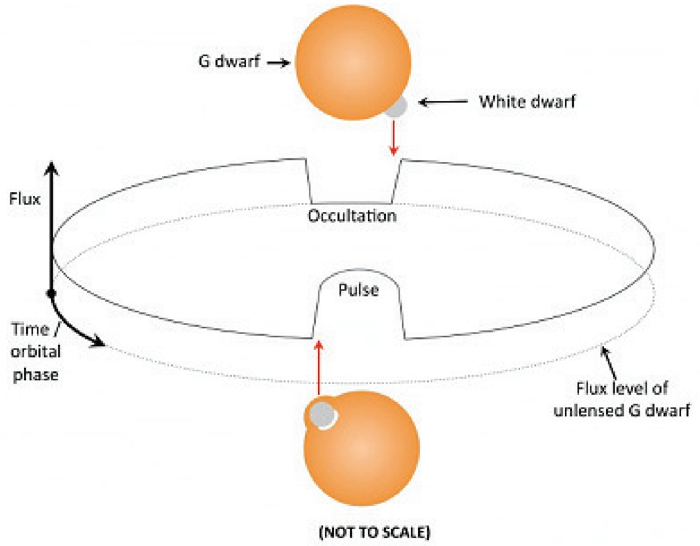
KOI-3278: A self-lensing binary star system

More than 40% of stars are in pairs that orbit around each other, called binary star systems. KOI-3278 is a pair of stars consisting of a white dwarf and a main sequence G-star with an orbital period of 88.18 days. This system produces the first ever case of periodic microlensing signal, based on data collected by NASA's Kepler planet-hunting space observatory. Previously theorized, around forty years ago, this phenomenon has never actually been observed directly until now.

A team of astronomers – lead by Ethan Kruse and Eric Agol - at the University of Washington in Seattle has discovered the very first known instance of a self-lensing binary-star system. A self-lensing effect is based on Einstein's theory of relativity: light does not have mass, but it is subject to gravity, so it is bended when passing a massive object.

The term "self-lensing binary" refers to a binary star system that is edge-on to the line of sight and in which one star causes a brightening of its companion – due to gravitational magnification, or "microlensing" – as it passes in front of the companion's disk.

KOI-3278 is also one example of an eclipsing Sirius-like system – a binary composed of a non-interacting white dwarf and a Sun-like (hotter) main-sequence star. The system is located in the constellation Lyra, and has been known for some time as a good candidate to host an extrasolar planet, as it had previously been identified to dim periodically. The latest study (Kruse & Agol, 2014) has revealed the companion is a white dwarf star, not a planet.



When the white dwarf eclipses its companion, its gravity magnifies the light, making the star appear very slightly brighter. Credit: Eric Agol / Ethan Kruse.

http://www.astro.washington.edu/users/eakruse

The primary star is very similar to the Sun. Scientists used the MCMC (*Markov Chain Monte Carlo*) analysis and stellar models to constrain the mass of the white dwarf to be ~63% solar (Kruse & Agol, 2014). When a WD is in a binary system, it magnifies its companion's light, causing a pulse – it gets briefly brighter instead of dimmer, like in a normal eclipse. To get a pulse instead of an eclipse, the alignment and orbit has to be very unique. The lensing effect allows the mass of the white dwarf to be estimated, which helps scientists to understand how similar binary systems may have evolved.

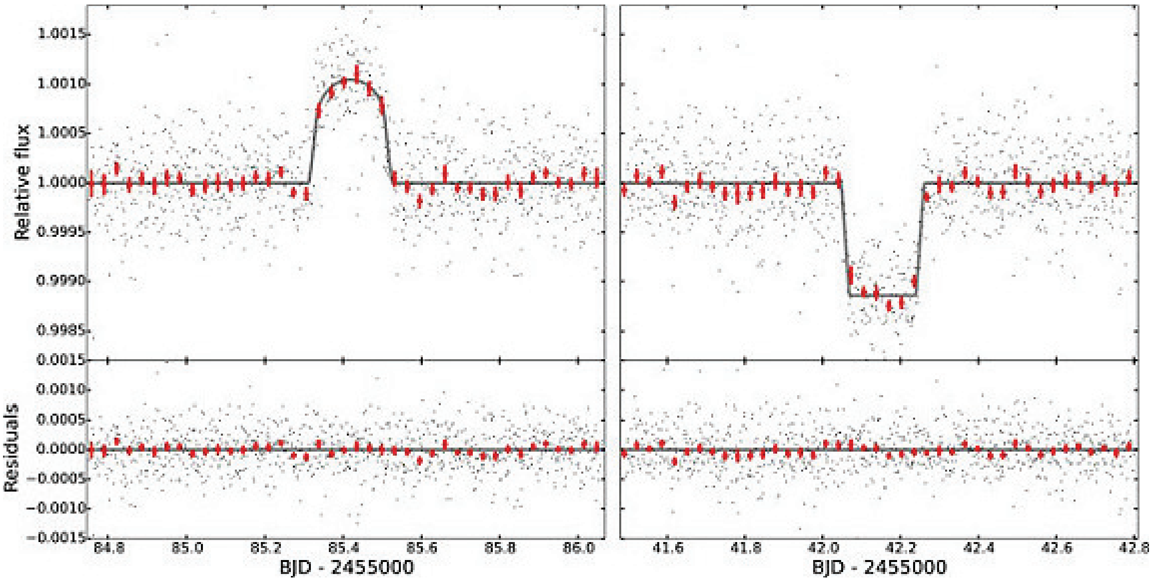
The magnification effect combined with the dimming provides a way of very accurate measures of the mass and radius of the white dwarf companion, which would be hard to achieve otherwise. White dwarfs are the burnt-out cores of former Sun-like stars, which fuse helium into heavier elements.

A Horseshoe Einstein Ring from Hubble. Pictured above, the gravity of a luminous red galaxy (LRG) has gravitationally distorted the light from a much more distant blue galaxy. More typically, such light bending results in two discernible images of the distant galaxy, but here the lens alignment is so precise that the background galaxy is distorted into a horseshoe -- a nearly complete ring. Credit: ESA/Hubble & NASA

Albert Einstein first proposed a phenomenon called gravitational lensing in 1915. This effect was experimentally confirmed long ago and is now a standard method of surveying galaxies and clusters. It is the focusing of light from more distant objects by a massive body, often producing multiple images. The first observational test of the theory was lensing of starlight during a total solar eclipse in 1919, when Arthur Stanley Eddington measured the deflection of starlight from stars in Hyades around the momentarily hidden Sun. A good historical overview of the experiment, written by Karl S. Kruszelnicki, can be found at *http://www.abc.net.au/science/articles/2001/11/05/94876.htm*

Most of the gravitational lenses in the past have been discovered accidentally. A search for gravitational lenses in the northern hemisphere (Cosmic Lens All Sky Survey, CLASS), done in radio frequencies using the Very Large Array (VLA) in New Mexico, led to the discovery of 22 new lensing extragalactic systems.

In the beginning of 1970's astrophysicists predicted that a similar lensing effect may occur in binary systems, but on a much smaller scale (Maeder, 1973). Maeder predicted that binary star systems in which one star is a compact object – a white dwarf, neutron star, or black hole – could cause periodic magnification of its companion star's light (instead of the standard eclipses), if the orbit happened to be viewed edge-on. A special case of microlensing is self-lensing, which occurs when both the foreground and background objects are part of the same binary system, which exactly is the case with KOI-3278.



Detrended and folded Kepler photometry of KOI-3278 presented as black points (all pulses and occultations have been aligned), overplotted with the best-fit model (gray line) for the microlensing pulse (left) and occultation (right). Red error bars show the mean of the folded data over a 45-min time scale. Bottom graphs show the residuals of the data with the best-fit model subtracted. BJD, barycentric Julian date. Image and description are taken from (Kruse & Agol, 2014).

For exoplanets, the effect of self-lensing is far too small to be seen. The problem is that in most binaries, the eclipse blocks far more light than the microlensing amplifies, meaning astronomers can't measure the effect of general relativity. In the KOI-3278 binary system, microlensing from the white dwarf boosts the light of its G-dwarf companion by only 0.1 percent (Kruse & Agol, 2014). What is extremely important, researchers could determine the WD mass and even its radius, which is about 1.1 percent of the Sun.

Those readers, who possess a good math background, may find a list of several important papers below, which present a theoretical basis of self-lensing in binary systems. KOI-2378 is the first system of that type discovered yet, and the Kepler space observatory, though its mission is completed, produced a huge volume of data to be analyzed. So new discoveries are waiting in line.

Ivan Adamin

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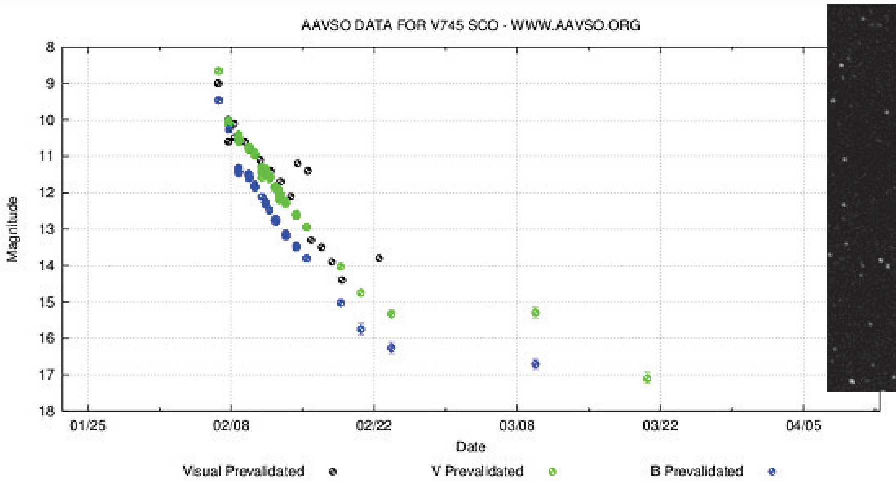
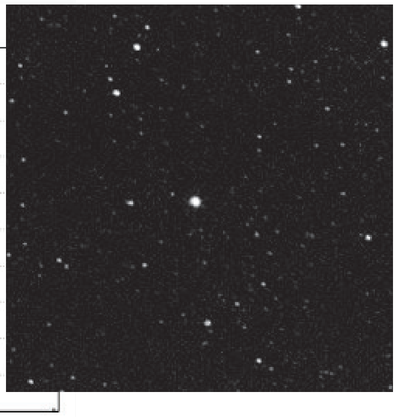
Outburst of the recurrent nova V745 Scorpii

An outburst of the recurrent nova V745 Sco (Nova Sco 1937) has been reported by Rod Stubbings from Australia. Observations made on 2014 February 6.694 UT revealed the star at visual magnitude 9.0. This is only the third recorded outburst of this nova, the others occurred in 1937 and 1989.

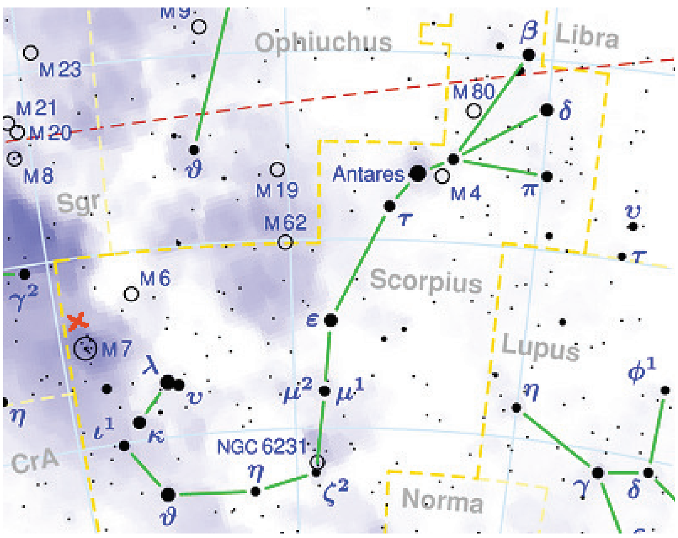




V745 Scorpii photometric observations between 2/6/2014 and 3/22/2014. The chart is generated by the AAVSO web service. The nova outburst was detected on February 6, 2014 by Rod Stubbings from Australia during an early morning observing session. The first CCD image was taken by Steve O' Connor (Bermuda)

Outbursts of recurrent novae are relatively rare events. The recurrent nova V745 Scorpii is located in Scorpius just about 1.5 degrees north of the open cluster M7. Previous outbursts of V745 Sco occurred in 1937 and 1989. The 1937 flare was detected 21 years later - in 1958 by Lukas Plaut - on plates taken by Hendrik van Gent at the Leiden Observatory. The object was later assigned its modern GCVS name - V745 Sco. It was classified as a nova on the basis of its outburst amplitude and light curve, although no spectroscopic observations were reported.

On July 30, 1989 William Liller (Chile) discovered on a sky patrol film a 9.7 magnitude star that was not there the night before. Its position was the same as for the nova that flared up on May 10, 1937, known as Nova Sco 1937 = V745 Sco. Duerbeck (1989) notes that in the 1989 outburst V745 Sco appears similar to RS Oph, but the optical spectrum evolves about three times faster.



Soon after the discovery the nature of the burst was confirmed by spectroscopic observations, made by Jonathan Powles: «I've identified the lines with best guesses based on the literature that I've found. Spectra from the first phase of the 1989 outburst are almost identical - these can be found in (Williams et al., 1991). The nova clearly has a strong He emission profile. Some interesting nebular lines developed quite quickly in 1989 - it will be interesting to see if they reappear. »

This recurrent nova fades quickly. Outbursts of 1937 and 1989 defined a typical very fast decline light curve: brightness dropped by 4m in 10 days. This should not be confused with a *supernova*, the last of which observed in our galaxy was Kepler's Supernova in 1604, just before the advent of the telescope in modern astronomy.

Historical notes and photometry of this and 9 other known galactic recurrent novae can be found in a massive paper: “Comprehensive Photometric Histories of All Known Galactic Recurrent Novae” (Schaefer, 2010).

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Left: The recurrent nova is located in Scorpius just about 1.5 degrees north of the open cluster M7. J2000: RA: 17h 55m 22.27s; Dec: -33d 14m 58.5s

RS Puppis: the light echoes calibrate standard candles for accurate distance measurements

Cepheids allow astronomers to measure vast distances across space. RS Puppis is an unusual cepheid embedded into an interstellar dust cloud illuminated by the variable light, enabling a phenomenon known as a light echo to be observed in details. Sparks (1994) showed that the polarization of a light echo can be used to measure its distance geometrically. This approach was used to determine the distance to RS Puppis with great accuracy, and hence calibrate the cosmic distance scale, based on the period-luminosity relation of classical Cepheid variables.

Cepheids are giants and supergiants which lie in the instability strip. Because they are intrinsically luminous, they can be seen to great distances. RS Puppis is a bright and easy to spot star for southern hemi-sphere observers. The star lies about 6,500 light-years away from Earth. It is over 10 times more massive and 200 times larger than our Sun. RS Pup periodically changes brightness over a six-week cycle (41.4 days), pretty long and comfor-table for visual observers. As RS Puppis expands and brightens, astronomers see some of the light after it is reflected from distant shells of dust and gas surrounding the star. Its average intrinsic brightness is 15,000 times greater than our Sun's luminosity. RS Pup remains one of the longest period Cepheids, in a class with stars like U Car (38.76 days) and SV Vul (45.01 days).

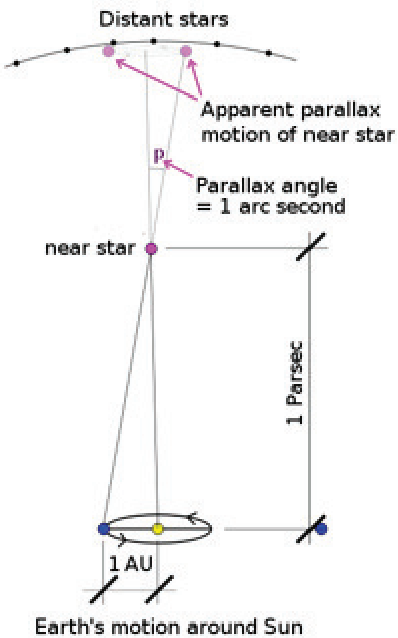
NASA's Hubble Space Telescope photo of the variable star RS Puppis and its surrounding cloud of gas and dust, accompanied by the light reflected from distant shells of dust. RS Pup is a Cepheid variable that brightens and dims as it expands and contracts.

Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)-Hubble/Europe Collaboration

By observing RS Puppis light fluctuations and recording reflections of light pulses moving across the surrounding nebula, scientists were able to measure these faint light echoes and calculate the distance very accurately.

Because of their geometry, light echoes can produce an *illusion* of superluminal speeds. A good explanation of this effect is given in AAVSO's note called "*Visible Superluminal echoes*" available at http://www.aavso.org/vsots_gkper. Light reflections allowed to determine the distance to the Cepheid variable RS Puppis quite reliably (with a margin of error of only one percent).

The bodies of which the intrinsic luminosity is well known are referred to as "standard candles". Cepheid variable stars were the key instrument in Edwin Hubble's 1923 conclusion that M31 is an external galaxy.



Trigonometric parallax can be measured only for nearby stars. Image credit: Chris Martin

Cepheids are good standard candles as their luminosity is quite high and can be computed from the Period-Luminosity Relation, first discovered in 1912 by *Henrietta Leavitt*. The most luminous Cepheids can be ~100K times more luminous than the Sun, which allows to use them as standard candles for distances up to 30-50 Mpc.

The only directly measurable distances in astronomy are those made by trigonometric parallax, which is useful for distances out to about 50 parsec for ground-based optical and a few hundred parsecs for space-based observa-tions. The accuracy is limited by the smallness of the motions (see the picture on the right). There are no Cepheids known this close to the Sun.

The first successful measurement of the distance to a star using trigono-metric parallax method was carried out by the German astronomer Friedrich Bessel in 1838, when he determined that 61 Cygni is 10.4 light-years away. More accurate recent measurements give a distance of 11.4 ly.

The nebula around RS Pup was discovered in 1961 by Swedish astronomer

Bengt Westerlund, who later became ESO Director in Chile (1970-74). In 1972, Robert Havlen published the first study of the nebula. Kervella et al. (2008) published a paper describing a method of distance calculation to the nebula by its geometric parameters, but later it was invalidated by Bond & Sparks (2009). In 2010, Hubble observed the star and its environment over a period of five weeks, capturing snapshots at different stages in its cycle, providing a basis for a more reliable result.

V838 Monocerotis

Another notable example of a star with a dusty nebula around and spectacular light echoes is V838 Mon. It is a red variable star in the constellation Monoceros about 20,000 light years from the Sun.

Left: These images show the evolution of the light echo around the star V838 in the constellation of Monoceros. They were taken by the Hubble Advanced Camera for Surveys in November 2005 (left) and again in September 2006 (right). The numerous whorls and eddies in the interstellar dust are particularly noticeable. Possibly they have been produced by the effects of magnetic fields in the space between the stars.

Credit: NASA, ESA and H. Bond (STScI)

Galactic light echoes are extremely rare. Before we can see echoes, there must have been a massive star explosion in the region. This remarkable event took place on January 6, 2002, one that had never been observed before, when previously unknown star suddenly brightened, just like a nova (Brown, 2002). But instead of a long dimming phase, it became brighter two months later. The third burst in April was even more powerful.

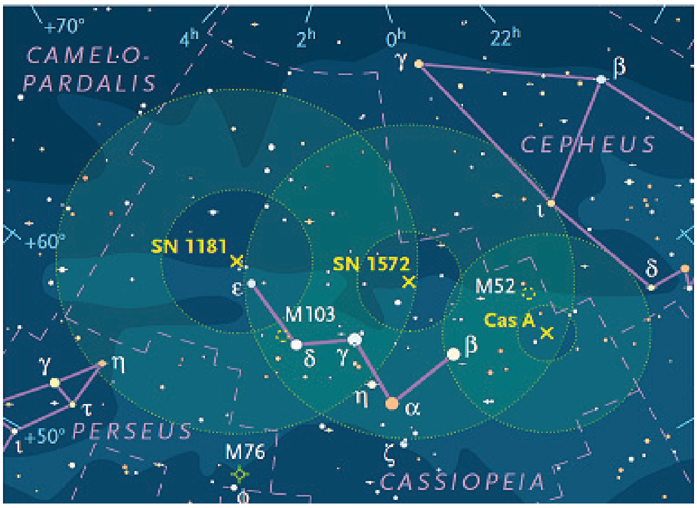
Early in the outburst, in mid-February 2002, a light echo surrounding V838 Mon was discovered by Henden et al. (2002). This allowed the distance to V838 Mon to be estimated from the evolution of the light echo. The cause of the eruption of V838 Mon and the nature of its progenitor are still unclear (Loon et al., 2004).

Series of images taken by the *Hubble Space Telescope* (above) did not reveal matter being blown away from an exploding object. What caused several cycles of brightening were light echoes illuminating an outer dust cloud. Two images above were taken by the HST in November 2005 and September 2006, showing no spherical shell around the star, but a quite irregular dust cloud highlighted in the vicinity of the central object. Unlike a classical nova, V838 Mon became progressively redder, eventually becoming the coolest known luminous star (Bond et al., 2003).

Initial estimates of the distance to V838 Mon done in (Munari et al., 2002) gave values of 0.6-0.8 kpc. These results were however based on a wrong interpretation of the observed expansion of the light echo. From a more realistic study of the echo structure (Bond et al., 2003) concluded that the distance is at least 6 kpc (Tylenda, 2005).

Hunting light echoes

The best places to search for light echoes are in the vicinity of our galaxy's historical supernovae. Particularly, blasts recorded in *1006* in Lupus, *1054* in Taurus (the remnant of which is known as the Crab Nebula), *1181* in Cassiopeia, *1572* in Cassiopeia ("Tycho's star"), *1604* in Ophiuchus ("Kepler's star"), and perhaps the late 17th century in Cassiopeia, the remnant of which is Cassiopeia A.



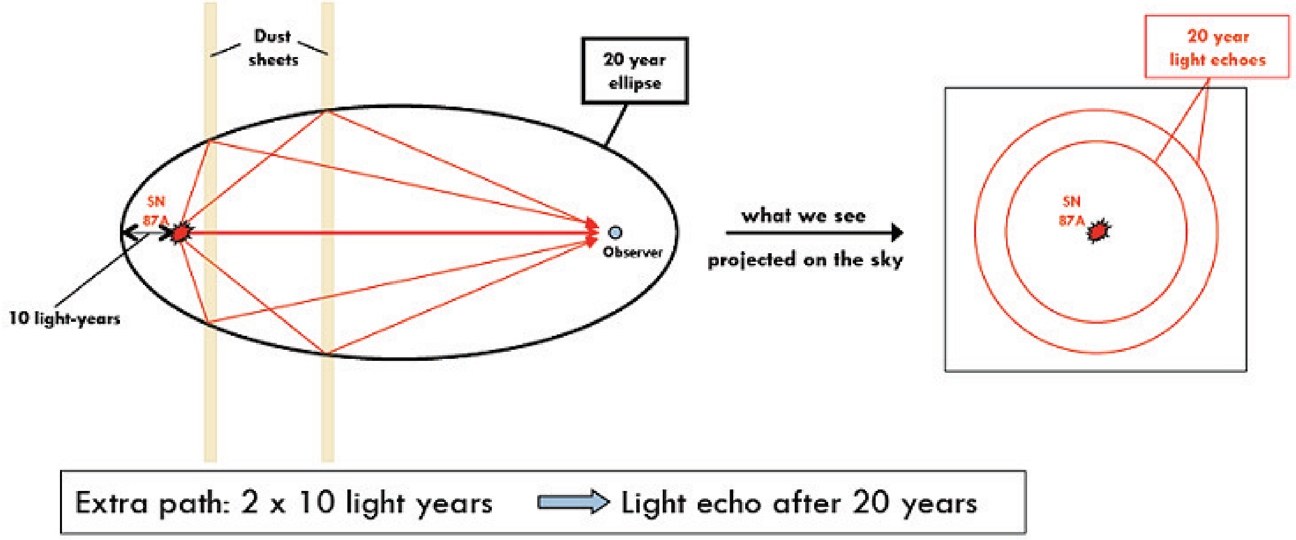
Right: Finder chart for light echoes around Supernova 1181, SN 1572 , and the 17th-century blast produced remnant Cas A. Credit: S&T June 2008 - Casey Reed / Source: Douglas L. Welch

More details on light echo observing targets can be read in the article "*How to Hunt for Supernova Fossils in the Milky Way*", written by Douglas L. Welch (S&T, June 2008) from McMaster University, Canada.

Basic geometry behind a light echo

While a flash from an exploding star travels out in all directions, it will still take years before it reaches the nearest dust cloud, heating it up. The cloud, which was too cold to detect directly before, begins to emit in infrared light. This infrared echo signal travels towards an observer, and due to a longer way it lags behind the original flash, which means it will arrive later for the observer. Though the second dust cloud is more distant from the star, the light will travel the same overall distance on its way to the observer, because of the geometric properties of an ellipse (as illustrated in the figure below). This means that light from both clouds will reach the Earth at the same time (see image below), resulting in two echoes simultaneously. A phenomenon known as *Visible Superluminal echoes.*

More at: http://www.spitzer.caltech.edu/images/2662-ssc2005-14d-Illustration-of-a-Light-Echo



Basic geometry behind a light echo: ellipsoids trace out surfaces of constant arrival time, causing an observer to see distant dust regions being highlighted by the exploded star as concentrated circles projected on the sky. Image credit: Armin Rest (Harvard), SuperMACHO & EHS collaboration

Ivan Adamin

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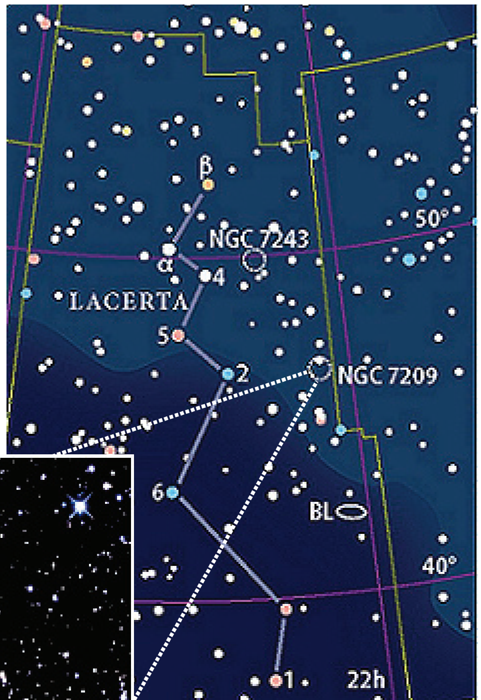
SS Lacertae: The non-eclipsing eclipsing binary

Among the brighter members of the open cluster NGC 7209, SS Lacertae has gained considerable attention during the past decades due to its extraordinary behavior, not typical of eclipsing systems: the complete cessation of eclipses in the middle of the twentieth century. SS Lac belongs to a small class of triple systems in which changes due to dynamical effects can be seen over a single human lifetime.

The discovery of variability of SS Lacertae is attributed to Henrietta Leavitt by Pickering (1907). The first light curve was published by Hoffmeister (1921) and was based on visual observations made from 1915 to 1918. Knowledge about the light variations of the SS Lacertae system, when it was still an eclipsing binary, comes entirely from visual and photographic measurements that go back more than a century but are, unfortunately, of rather poor quality.

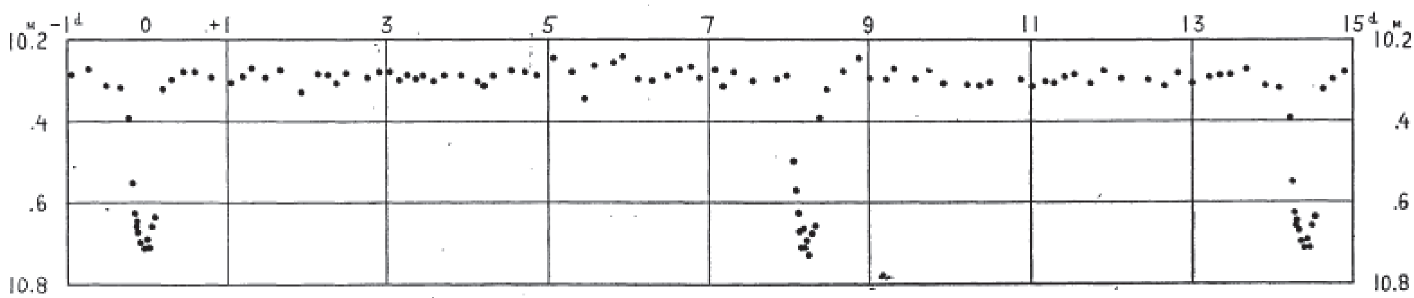
One of the most important early photographic light curves of SS Lac was published by Dugan and Wright in 1935, distinguishing SS Lacertae as an eclipsing system with a period of 14.4 days. Measurements were based on the data from plates obtained at the Harvard College Observatory. Eclipses were observed photographically and visually early in the 20th century, but stopped some 60 or 70 years ago.

The orbit of SS Lac is clearly eccentric (e=0.11; Zakirov & Azimov, 1990), as shown by the displacement of the secondary eclipse: eclipses were of equal depth with the secondary eclipse occurring at a phase of 0.57 (Schiller et al., 1991).



Open cluster NGC 7209 lies in Lacerta. It is well-detached from the backround sky in a field spanning the apparent diameter of the full Moon. SS Lacertae is marked with a white arrow on the left image.

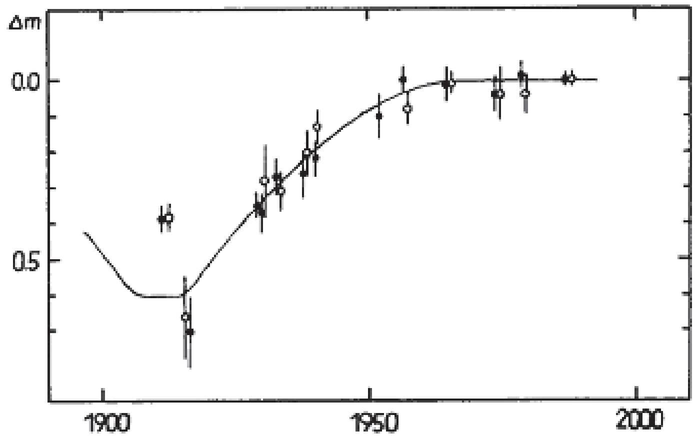
A number of scenarios have been proposed to explain this phenomenon. The cessation of eclipses in a binary star is a rare phenomenon that can most often be explained by the presence of a third object in the system inducing perturbations in the orbital elements of the inner pair (Torres, 2001). Lehmann (1991) re-measured original plates material from the Sonneberg Observatory (1890-1989), presenting the first evidence that the depth of the eclipses had changed over the years. He proposed a hypothesis that visible cessation of eclipses is due to the presence of an unseen third star in the system, which is gradually changing the inclination angle of the inner pair. It is not clear, however, whether the cessation of eclipses in SS Lac was gradual, as asserted by Lehmann (1991), or whether it happened suddenly (see Milone et al. 1992).



Mean photographic light curve of SS Lacertae showing a 14.4-days period. The average photographic magnitude at normal brightness is 10.28, and 10.69 in minimum (historic chart from Dugan & Wright,1935)

Higher resolution spectroscopic observations made by Etzel, Volgenau, & Nguyen (1996) did show double lines in the spectra, and this was immediately confirmed by Stefanik et al. (1996) and Etzel & Volgenau (1996). A double-lined spectroscopic orbit for SS Lacertae was published by Tomasella & Munari (1998) showing that the binary was intact and that the period had not changed significantly. This left little doubt that the reason the system is no longer eclipsing is a change in the orientation of the orbit, most likely brought about by the presence of a third star in the system. (Torres & Stefanik, 2000).

Adding to its interest, SS Lac is a member of the open cluster NGC 7209, and therefore other information such as estimates of the age, distance, and metal abundance is available. Proper-motion studies of SS Lac have shown that it shares the mean motion of NGC 7209 on the plane of the sky. The probability of membership, according to Platais (1991), is 97%.



Right: The disappearance of the eclipsing amplitude of SS Lacertae. Filled circles represent primary minima, while open circles correspond to secondary minima. The graph is from (Lehmann, 1991; IBVS 3610)

Remeasured Harvard plates data and other available published data sets revealed that the depth of the primary minimum increased between the 1890s and early 1900s and decreased in the 1920s and 1930s. According to this data, the largest eclipse amplitude was around 1911 (Milone et al., 2000).

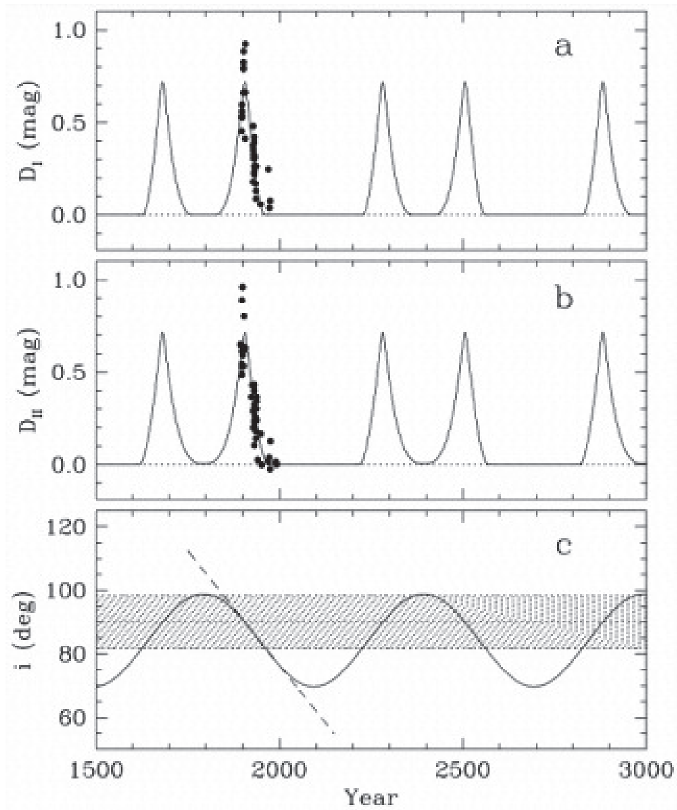
From photographic archive examination, Mossakovskaya (1993) concluded that the cessation of eclipses in SS Lac had occurred between the mid-1930s and the 1940s, although a limit in the 1950s was suggested initially by Zakirov & Azimov (1990). Twelve spectra obtained during 1982-1984 revealed only single lines and no detectable radial-velocity variation.

Few examples of this phenomenon are known, among them are:

- *AY Mus* (Soderhjelm, 1974)
- *IU Aur* (Harries, Hilditch, & Hill, 1998; Schiller, 1981)
- *RW Per* (Schaefer & Fried, 1991)
- *V907 Sco* (Lacy, Helt & Vaz, 1999)

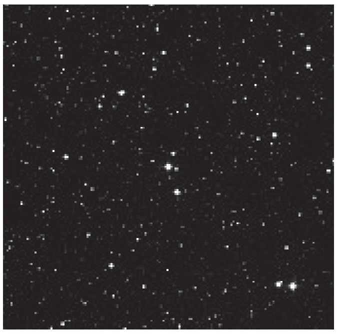
On 1996 July 1.47 UT, spectroscopic observations provided a velocity difference of 174 km/s between the components, corresponding to orbital phase 0.78 from the eclipse ephemeris of Dugan and Wright (1935). That confirmed past assumptions: SS Lac was still a binary system. (Etzel et al., 1996; IAUC, 6429, 2)

The most difficult problem faced by all researchers attempting to fit the light curves of SS Lac has been the fact that the inclination angle of the binary changes with time. Further extensive spectroscopic observations were presented by Torres & Stefanik (2000), which demonstrated the existence of a third body.

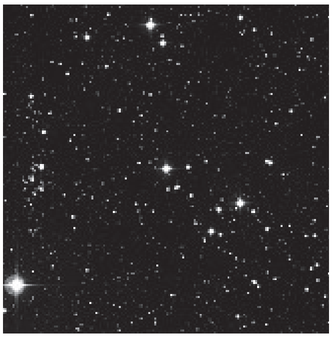


Long-term behavior of the eclipse amplitudes for the primary (a) and secondary (b) minima, resulting from the fit to the measurements based on the regression of the nodes effect. The cycle repeats with a period Pnode = 600 yr (see text). Panel (c) displays the expected behavior of the inclination angle according to this model. The shaded area represents the range in which eclipses are possible (Torres, 2001)

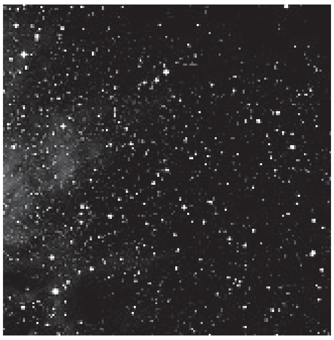
Torres & Stefanik determined the orbital elements of the distant third object, with a period of about 679 days and a slightly eccentric orbit. They also detected apsidal motion for the first time for the SS Lac system. The nodal cycle is found to be 600 yr, within which two eclipse "seasons" occur, each lasting about 100 yr. The non-eclipsing status of the system is expected to continue, no further eclipses are expected until shortly after the year 2200, if the present model of orbital motions in the SS Lac system is correct (Torres, 2001). Clearly, if SS Lacertae was an eclipsing binary, the dynamical nature of this system has changed dramatically.



RW Per



IU Aur



V699 Cyg

AH Cep

Known eclipsing systems with an observed or possible cessation of eclipses, or with changing minima depths (upper: 15 arc mins DSS field of view)

Object Designation	RA (J2000)	DEC (J2000)	Period	Mag. Range	Reference
RW Persei	04 20 16.8	+42 18 52	13.198904	9.68 - 11.36 V	Olson et al., 1992; AJ, 103, 256
IU Aurigae	05 27 52.4	+34 46 58	1.81147536	8.19 - 8.83 V	Özdemir et al., 2003; A&A, 403, 675
SV Gemini	06 00 41.0	+24 28 26	4.0061216	10.55 – 10.62 V	Guilbault et al., 2001; IBVS, 5090, 1
HS Hydrae	10 24 36.8	-19 05 33	1.568042	8.07 - 8.61 V	Zasche & Paschke, 2012; A&A, 542, 23
V0685 Cen	11 24 26.6	-57 43 40	1.190964	9.4 - 9.8 p	Mayer et al., 2004; IBVS, 5563, 1
AY Muscae	11 31 40.3	-65 16 17	3.205558	10.51 - 10.8 B	Söderhjelm, 1975; A&A, 42, 229
V907 Scorpii	17 56 55.6	-34 45 01	3.776277	8.61 - 9.2 V	Lacy et al., 1999; AJ, 117, 541
V699 Cygni	20 17 00.3	+39 08 20	1.55152	12.0 - 13.0 p	Zakirov & Azimov, 1991; IBVS, 3667, 1
SS Lacertae	22 04 41.6	+46 25 38	14.41629	10.1 - 10.5 p	Torres, 2001; AJ, 121, 2227
AH Cephei	22 47 52.9	+65 03 44	1.7747505	6.78 - 7.07 V	Drechsel et al., 1989; A&A, 221, 49
QX Cassiopeiae	23 58 43.1	+61 09 39	6.00471	10.19 - 10.7 V	Bonaro et al.,2009; BAAS, 41, 301

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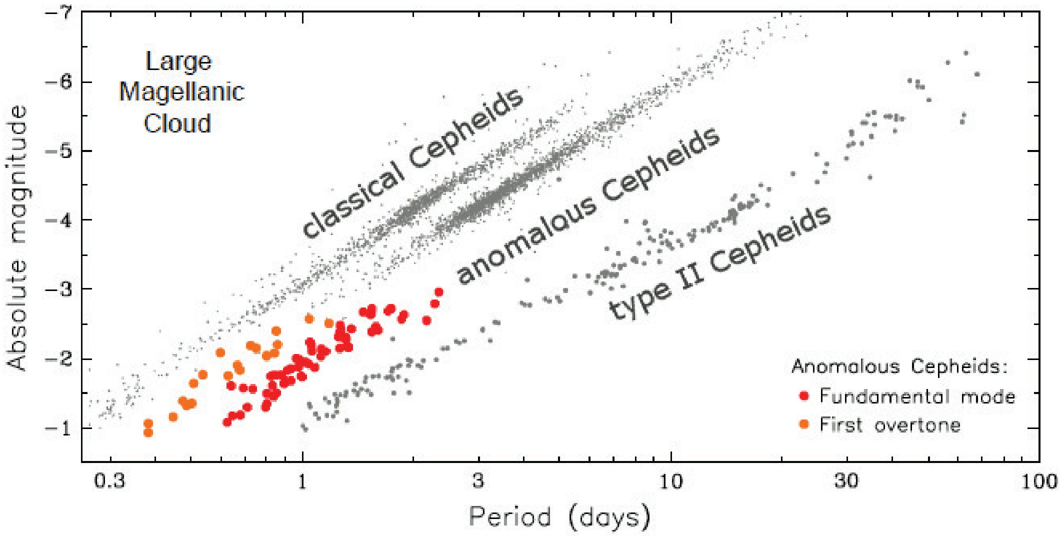
BL Boötis stars - anomalous Cepheids

BL Boö is the prototype of a subclass of pulsating variable stars called the Anomalous Cepheids. These stars are similar to classical Cepheid variables, but they do not follow the same relationship between their period and luminosity.

The *Type II Cepheids* are population II variable stars which pulsate with periods typically between 1 and 50 days. These are typically metal-poor, old and low mass objects. The Type II Cepheids are divided into several subgroups by their period length. Stars with periods between 1 and 4 days are of the *BL Her* subclass, 10–20 days belong to the *W Virginis* subclass, and stars with periods greater than 20 days belong to the *RV Tauri* subclass.



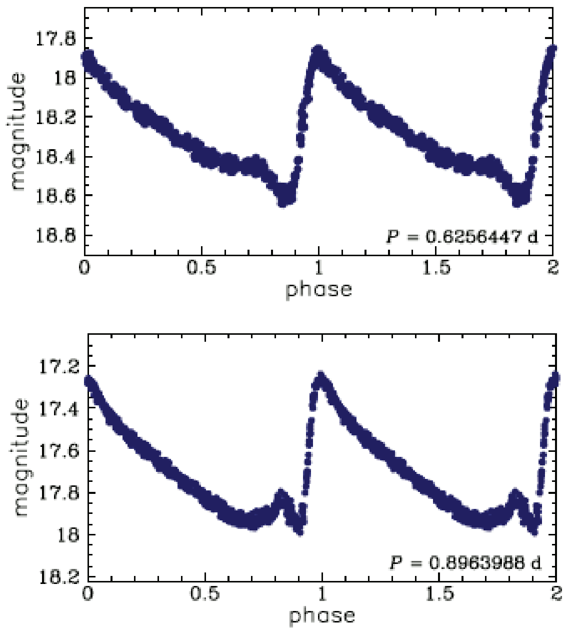
This figure illustrates the Period-Luminosity diagram for Cepheids in the Large Magellanic Cloud (Soszyński et al., 2008). Red and orange points show the position of anomalous Cepheids pulsating in the fundamental mode and first overtone, respectively. The data has been collected by the OGLE project. Image credit: http://ogle.astrouw.edu.pl

BL Boötis is a member of the NGC 5466 globular cluster (Zinn & Dahn, 1976; Zinn & King, 1982). Anomalous Cepheids are metal poor and have average masses around 1.5 solar masses. They have periods from a few hours to over 2 days, depending on whether they pulsate in the fundamental or first overtone mode. Typical light curves are asymmetric, with a sharp rise to the maximum and a slow decline. A small bump near minimum light is often seen.

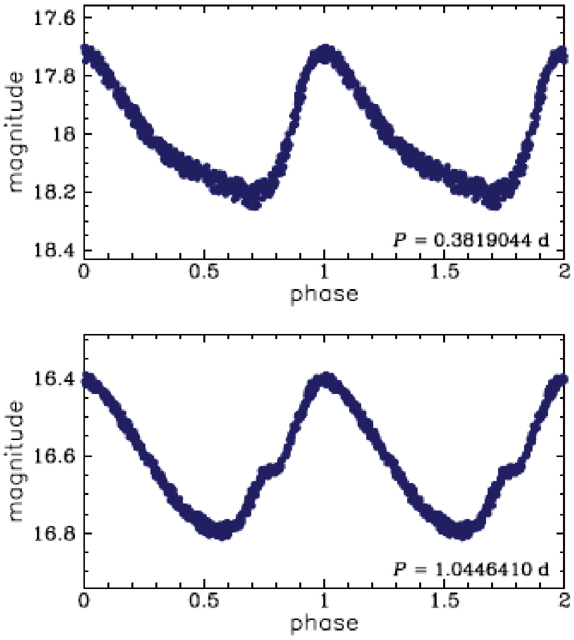
The difference between the anomalous and the Population II classes of Cepheids manifests itself in the Period Luminosity relation (see the image above). The distinctive features of these variable stars are the short pulsational period (in the period range of RRab variables) and a luminosity, which is about 2 magnitudes higher than for RR Lyrae stars of similar period. The GCVS4 refers to these stars as BLBOO variables, after variable V19 (also known as BL Boötis) in NGC 5466.

Light curves of anomalous Cepheids look very similar to the light curves of RR Lyrae stars and classical Cepheids, thus it is very hard to make a distinction between these types of pulsating stars. However, anomalous Cepheids are intrinsically much brighter. Most of the known ACs are found in nearby dwarf spheroidal galaxies, but a few of them are known in globular clusters.

First-overtone anomalous Cepheids have periods from about 0.3 days to slightly over 1 day. Generally, they have smoother light curves than the fundamental-mode pulsators, with rounded maxima and minima, although some stars exhibit a sharper maximum (Soszyński et al. 2008).



Typical light curves of anomalous Cepheids pulsating in the fundamental mode: OGLE-LMC-ACEP-068 (top), OGLE-LMC-ACEP-007 (bottom). Soszyński et al. (2008) - http://ogle.astrouw.edu.pl



Typical light curves of the first-overtone anomalous Cepheids pulsating: OGLE-LMC-ACEP-020 (top), OGLE-LMC-ACEP-050 (bottom).
Soszyński et al. (2008) - http://ogle.astrouw.edu.pl

The OGLE project - http://ogle.astrouw.edu.pl - discovered as many as 83 anomalous Cepheids in the Large Magellanic Cloud, while the Small Magellanic Cloud has only a few candidates (Soszyński et al., 2008 & 2010). The properties of Cepheids with periods between 0.8 and 3 days in the gene-ral field, globular clusters, and nearby spheroidal galaxies have been discussed in details by Sandage, Diethelm, & Tammann (1994). The evolutionary stage of anomalous Cepheids is not known.

XZ Ceti

Photometric variability of XZ Ceti (HD 12293) was first detected by Hoffmeister (1933). This peculiar pulsating variable has a period of 0.823156 day. It is the only anomalous Cepheid known in the Galactic field. It differs from the ordinary classical Cepheids in several respects, but the most distinctive feature is cycle-to-cycle variability of the light curve. The radial velocity phase curve is not stable either. The pulsation period is subjected to strong changes on various time scales including a very short one (Szabados et al., 2013).

The available photometric observations of XZ Ceti (e.g. Dean et al., 1977; Teays & Simon, 1977; Hipparcos, ESA, 1997 and ASAS, Pojmanski, 1997) cover about thirty years. Yet, continued observations are necessary to study the deviations from regularity, to determine their time scale, as well as to confirm the binarity of XZ Ceti and to study its role in the observed peculiar behavior.

The list of known anomalous Cepheids has been compiled by Nemec et al. (1994) and more recently by Pritzl et al. (2002). A modern catalog of ACs is available from the OGLE project website.

Several possible anomalous Cepheids located in our galaxy

Object Designation	RA (J2000)	DEC (J2000)	Var. Type (VSX)	Period, d	Mag. Range
BL Boötis	14 05 40.5	+28 29 12	ACEP	0.8213010	14.45 - 15.10 V
XZ Ceti	02 00 16.6	-16 20 46	ACEP	0.8231561	9.24 - 9.71 V
UY Eridani	03 13 39.1	-10 26 32	ACEP	2.21328	10.93 - 11.66 V

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Revised elements of seven known red variable stars from the article «59 New Red Variable Stars»: NSVS 16324859 and NSVS 16329544 are confirmed to be Mira variables

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2 – ivan.adamin@gmail.com; The VS-COMPAS Project

Abstract: A careful review of the article «59 New Red Variable Stars» - published in PZP ("Peremennye Zvezdy", Prilozhenie, vol. 14, N 4 (2014)) - revealed that elements and variability types could be refined for several red variable stars. We were able to classify NSVS 16324859 and NSVS 16329544 as Mira variables; furthermore, the identification of NSVS 16329544, which was obviously misidentified in the original article, could be improved. Magnitude ranges are now given in V. Most stars' data required a deblending procedure to eliminate light contamination from neighboring stars and get an improved magnitude range.

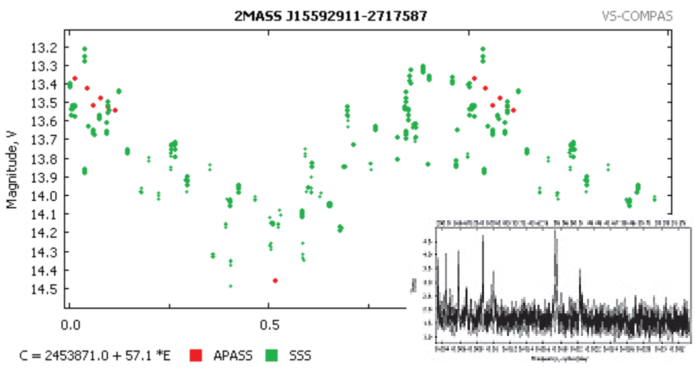
Revised elements of seven known variable stars from the article «59 New Red Variable Stars» (Sergey et al, 2014) are presented in this article. For many objects in the mentioned paper, no periods or epochs have been published. This has motivated the authors to undertake a review of those stars and try to improve their elements using publicly available data from photometric surveys.

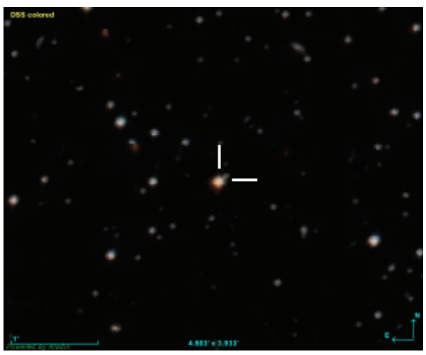
Period search and analysis was made by Siarhey Hadon using the "VSC Effect" custom software created by A. Prokopovich and I. Adamin, which finally led to a refined period value and, in some cases, an updated variability class.

In addition to using ASAS-3 photometry, a search for additional data in other sky surveys. such as the Northern Sky Variability Survey (Wozniak et al., 2004), the Catalina Realtime Transient Survey (Drake et al., 2012), the AAVSO Photometric All-Sky Survey (Henden et al., 2012), was performed for each object. Whenever possible, corresponding photometric data sets were included into the analyses to check if the resulting period matches the value determined by Sergey et al. (2014). This led to an improved quality and reliability of the results.

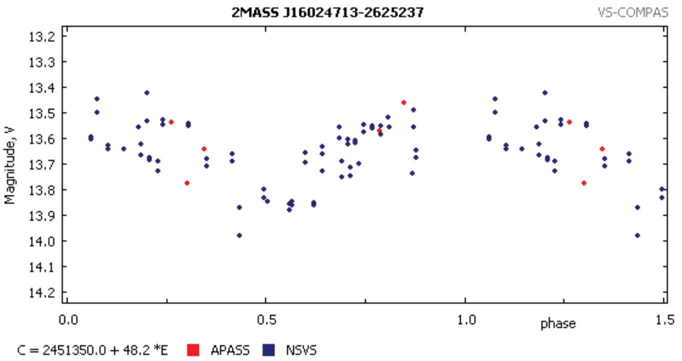
Below a table containing seven objects along with their individual 2MASS identifications, short research summary and remarks is presented. Updated elements and light curves along with the data published previously are summarized in the table for comparison.

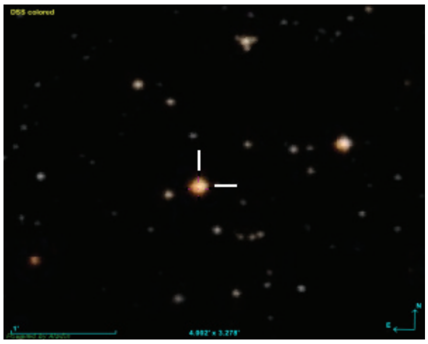
2MASS J15592911-2717587. Though the period from Sergey et al. (2014), based on the NSVS data, looks fine, checking the SSS data set combined with photometry from the APASS gives another period of 57.1 days, valid for HJD 2453600-2456500. The NSVS range has been corrected taking into account light contamination from neighboring stars of comparable brightness.



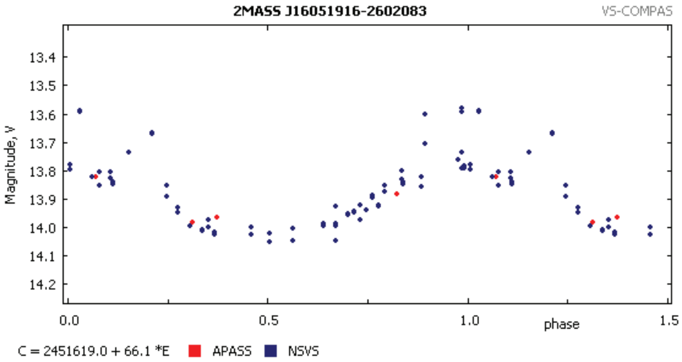


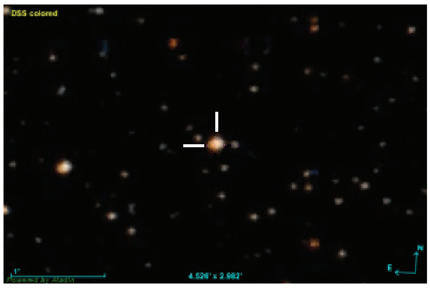
2MASS J16024713-2625237. For this star a period was not determined in the original paper. Combining APASS and NSVS data for the object results in a peak on the periodogram, corresponding to a period of 48.2 days.



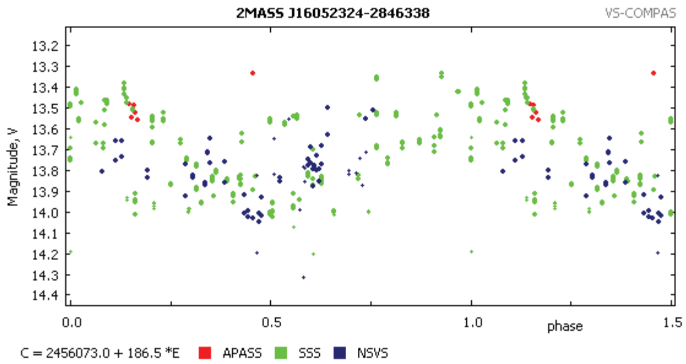


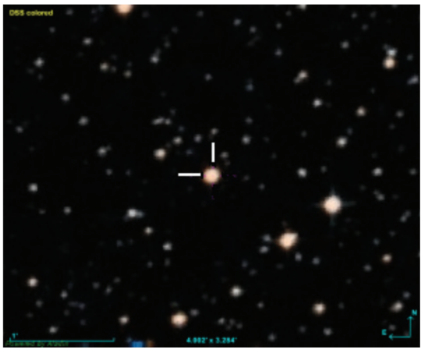
2MASS J16051916-2602083. Detailed analysis of the APASS and NSVS data revealed two periods for the star: 66.1 and 85.8 days. APASS points allowed to shift to the V scale. The period of 86 days presented in the original paper is not the primary one: the NSVS data contains a full cycle, which is clearly shorter than 86 days and corresponding to the period of 66.1 days.



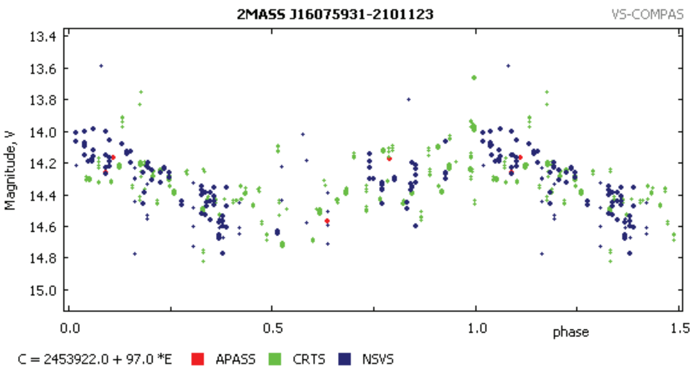


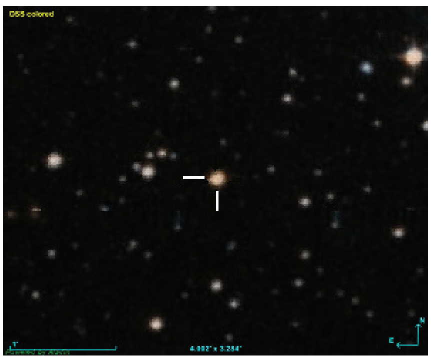
2MASS J16052324-2846338. For this star a period was not determined in the original paper. Combining NSVS, APASS and SSS data for the object results in a peak corresponding to a period of 186.5 days.



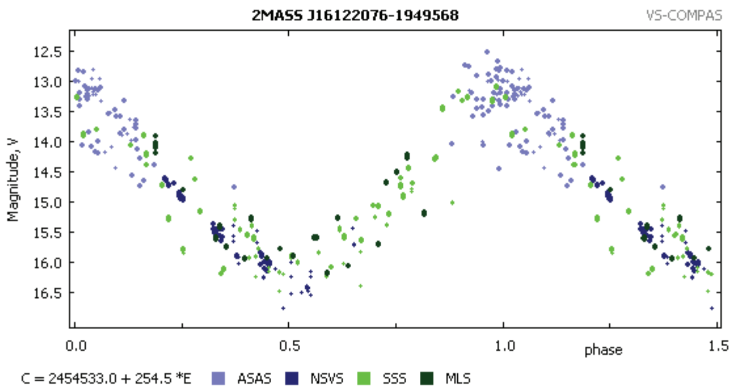


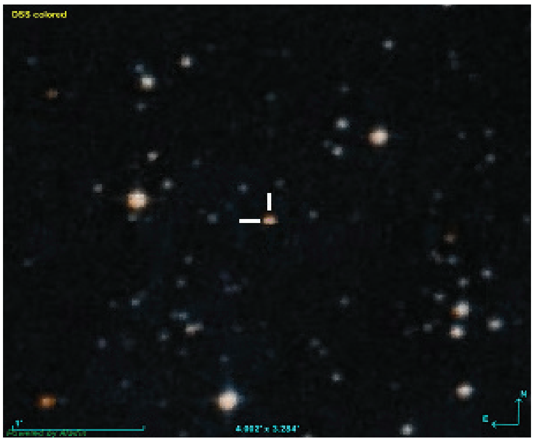
2MASS J16075931-2101123. The period of 76 days presented in the original paper does not seem to fit the NSVS data it is based on. Combining the NSVS data with CRTS photometry for this star results in a strong peak around 97 days instead of 76. This matches the two NSVS datasets well, providing two minimums separated by exactly three cycles of 97 days.





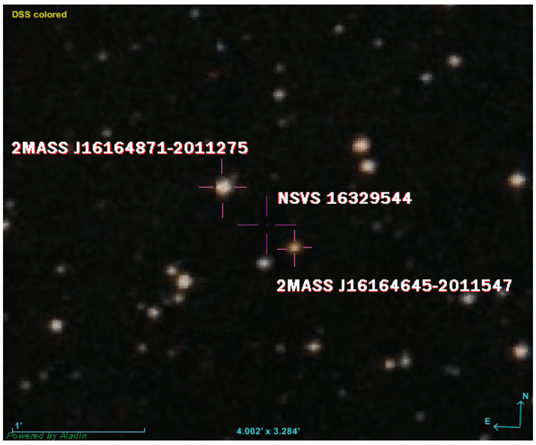
2MASS J16122076-1949568. This star is particularly interesting, as all major surveys boast photometric data, which allows to build a solid light curve with a magnitude range of roughly 3.3 mag! Again, the original paper does not provide data on the period, so this one instantly became a new Mira variable with a pulsation period of 254.5 days.





2MASS J16164645-2011547. This designation is not present in the original paper, but there are reasons to believe that the object 2MASS J16164871-2011275 presented as a variable in Sergey et al. (2014) is a mis-identification. The NSVS 16329544 data set belongs to 2MASS J16164645-2011547, a near-infrared-bright star with a J-K index of 1.54, which is typical of a red variable.

See the SDSS field image below, displaying the NSVS position and three nearest stars to it. Combining a data from the NSVS 16329544 and SSS_J161646.5-201154 produces a solid light curve with a period of 324 days and a magnitude range of 3.0. Thus, 2MASS J16164645-2011547 is considered a Mira pulsating variable star. The minimum occurs at phase 0.65.



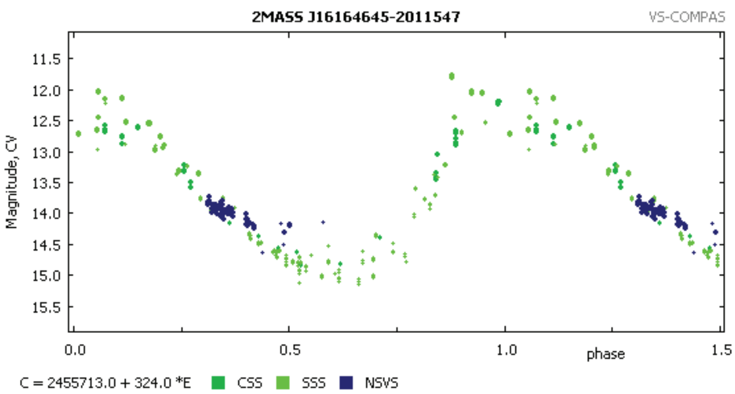


Table 1. – *Updated elements (typed in bold) of seven red variables published by Sergey et al (2014).*

	2MASS	Cross-identifications	Var. Type	Epoch (HJD)	Period (d)	Mag. Range	Src *
1	**2MASS J15592911-2717587**	UCAC4 314-082829 USNO-B1.0 0627-0473223 NSVS 19106759	**SR** SR:	**2453871** 2451632	**57.1** 59.6:	**13.3-14.4 V** 12.65-13.20 R1	**VSC** PZP
2	**2MASS J16024713-2625237**	UCAC4 318-085039 USNO-B1.0 0635-0372143 NSVS 19110215 IRAS Z15597-2617 AKARI-IRC-V1 J1602471-262523	**SR** LB	**2451350** –	**48.2** –	**13.45-13.85 V** 11.30-11.70 R1	**VSC** PZP
3	**2MASS J16051916-2602083**	UCAC4 320-084536 USNO-B1.0 0639-0365713 NSVS 19113044 IRAS Z16022-2553 AKARI-IRC-V1 J1605191-260209	**SRB** SR:	**2451619** 2451617	**66.1** 86:	**13.7-14.0 V** 11.30-11.75 R1	**VSC** PZP
4	**2MASS J16052324-**	UCAC4 307-084234 USNO-B1.0 0612-0364147	**SR** LB	**2456073** –	**186.5** –	**13.4-14.0 V** 12.5-13.05 R1	**VSC** PZP

	2MASS	Cross-identifications	Var. Type	Epoch (HJD)	Period (d)	Mag. Range	Src *
	2846338	NSVS 19113545 NSVS 19148819					
5	**2MASS J16075931-2101123**	UCAC4 345-079812 USNO-B1.0 0689-0344635 NSVS 19115455 NSVS 16320364	**SR** SR:	**2453922** 2451303	**97** 76	**14.0-14.7 V** 13.2-13.7 R1	**VSC** PZP
6	**2MASS J16122076-1949568**	UCAC4 351-079376 USNO-B1.0 0701-0332188 NSVS 16324859 IRAS Z16094-1942 AKARI-IRC-V1 J1612207-194957	**M** LB:	**2454533** –	**254.5** –	**12.7-<16.0 V** 12.50-14.50 R1	**VSC** PZP
7	**2MASS J16164645-2011547**	USNO-B1.0 0698-0343637 NSVS 16329544 SSS_J161646.5-201154 IRAS 16138-2004 AKARI-IRC-V1 J1616464-201155	**M** LB:	**2455713** –	**324** –	**12.0-15.0 CV** 13.50-14.10R	**VSC** PZP

*** VSC** = The VS-COMPAS Project**;** **PZP =** "Peremennye Zvezdy", Prilozhenie**.**

Remarks on objects:

1. J-K = 1.17. NSVS magnitudes are contaminated by 2MASS J15593087-2717312 (J-K = 0.44, V = 15.4, sep. 36"), 2MASS J15593254-2717586 (J-K = 0.42, V = 15.8, sep. 45"), 2MASS J15593254-2717586 (J-K = 0.42, V = 15.8, sep. 45"), 2MASS J15593244-2717248 (J-K = 0.54, V = 16.4, sep. 55"), 2MASS J15593258-2718322 (J-K = 0.55, V = 16.8, sep. 57"). Range has been corrected. The table gives elements for HJD 2453500-2456500.
2. J-K = 1.37. NSVS magnitudes are contaminated by 2MASS J16024843-2625284 (J-K = 0.61, V = 16.4, sep. 18"), 2MASS J16024639-2625492 (J-K = 0.54, V = 16.7, sep. 27"), 2MASS J16024511-2624594 (J-K = 0.61, V = 17.4, sep. 36"). Range has been corrected. Sp. Type – M7.
3. J-K = 1.31. Other period: Max= 2451363+ 85.8* E.
4. J-K = 1.22. NSVS magnitudes are contaminated by 2MASS J16052547-2846214 (J-K = 0.62, V = 16.3, sep. 31"), 2MASS J16052667-2846554 (J-K = 0.63, V = 16.7, sep. 50"). Range has been corrected.
5. J-K = 1.26. NSVS magnitudes are contaminated by 2MASS J16080212-2101079 (J-K = 0.47, V = 15.1, sep 39"). Range has been corrected.
6. J-K = 1.41.
7. J-K = 1.54. Wrong position/identification in Sergey et al. (2014). The variable star is 2MASS J16164645-2011547, not 2MASS J16164871-2011275.

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Acknowledgements: This publication has made use of the SIMBAD and VizieR databases operated at the Centre de Donnees Astronomiques (Strasbourg) in France, of the International Variable Star Index (AAVSO), and of the Two Micron All Sky Survey (2MASS).

A revision of NSV 13538 = NSVS 17231162

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*Abstract: A revision of the variable star NSV 13538 is presented. Light curve elements were improved by using modern data from photometric surveys available online. The following photometric elements of the minimum of the Long Secondary Period were found: Min = HJD 2454611 + 324 * E.*

NSV 13538 was reported to be a variable by H.Shapley & E.M.Hughes (1934). In 1971 the star was added to the Atlas of Finding Charts for Variable Stars (Tsessevich & Kazanasmas, 1971). Doing a search for new variable stars as a part of the VS-COMPAS project, NSVS 17231162 was found to be a variable star in May 2013. Comparing its coordinates with the VSX database records, the star was found to be the same as NSV 13538.

The Northern Sky Variability Survey (Wozniak et al., 2004) data has a moderate resolution, thus cross-identifications were helpful in getting a more precise position, as the NSV position may have not a high accuracy as well. This allowed us to obtain photometric data from other surveys. The corresponding entry in the ASAS-3 database, ASAS J210711-1300.3 has a very good coverage of at least 8 pulsation cycles, which led to a reliable period determination. The data from the APASS complements the ASAS-3 and NSVS measurements.

The light curve of this star shows large-amplitude sharp minima. Small amplitude short term variability has been lost in the noise in that particular case. The star was initially classified as E: in the NSV catalogue: the LSPs usually show eclipsing-like deep minima profiles.

Detailed periodogram analysis of this star's photometry using the method described by Lafler and Kinman (1965) revealed a strong peak corresponding to a period of 324 days. Photometric elements of the LSP minimum are the following:

Min = HJD 2454611 + 324 * E

The ASAS-3 photometric coverage was crucial for the period determination, since NSVS data lacks a major part of the light curve (c.f. Figure 2). The combined light curve folded with a period of 324 days boasts datapoints at all phases.

The magnitude range has been corrected for this object, taking into account the photometric properties of its close neighbor:

- 2MASS J21071201-1259554
  (J-K = 0.93, V = 17.81, sep. 26")

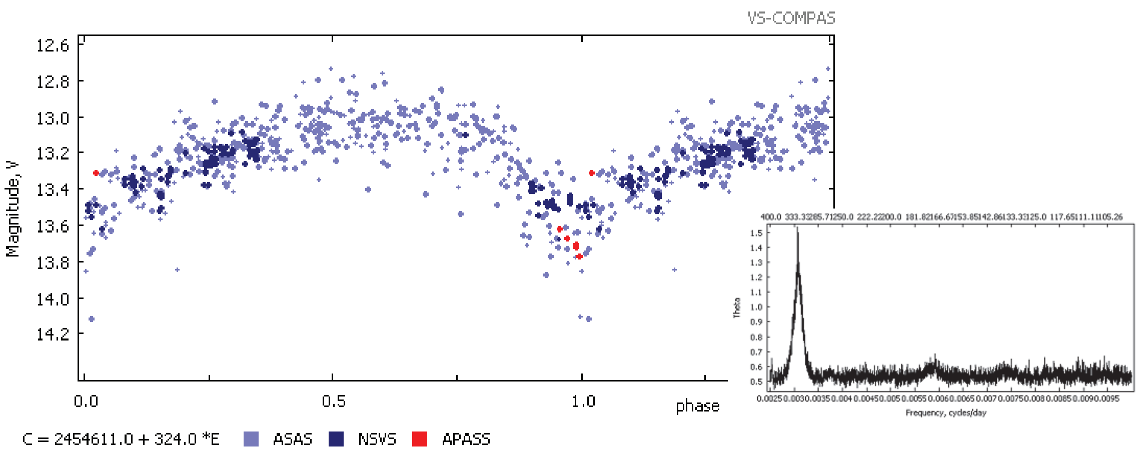
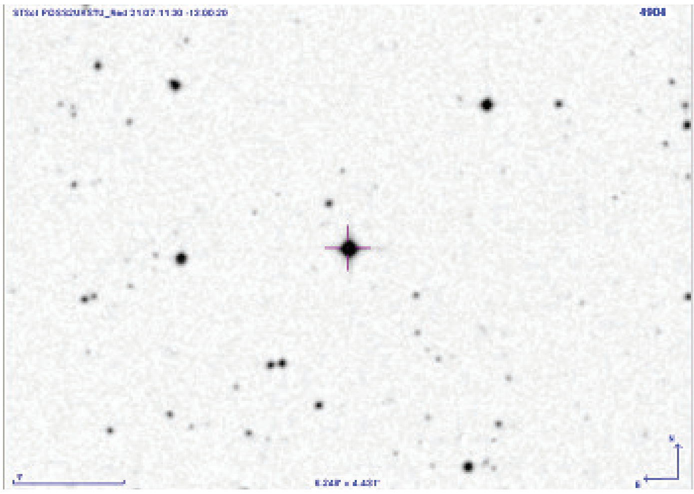


Figure 1. - Periodogram analysis shows a strong peak corresponding to a period of 324 days. The APASS data nicely complements the data from the ASAS-3 and NSVS. J-K = 1.11

Performing a deblending procedure of the available photometric data for NSV 13538 was necessary to confirm the real magnitude range and fit the minimum between data sets taken from different surveys.

Table 1. – A short summary of NSVS 17231162 data with updated elements.



NSV 13538 = NSVS 17231162	
Constellation	Aquarius
Other Names	2MASS J21071127-1300203 ASAS J210711-1300.3 GSC 05779-01662 HV 6236 UCAC4 385-156313
Coordinates	21 07 11.28 -13 00 20.4 (J2000.0)
Mag. range	12.9 - 13.8 V
Epoch	24 May 2008 (HJD 2454611)
Period	324 days
Var. type	SR

Appendix. Table 1 provides a summary of the target star. The given epoch corresponds to a minimum of the Long Secondary Period (LSP).

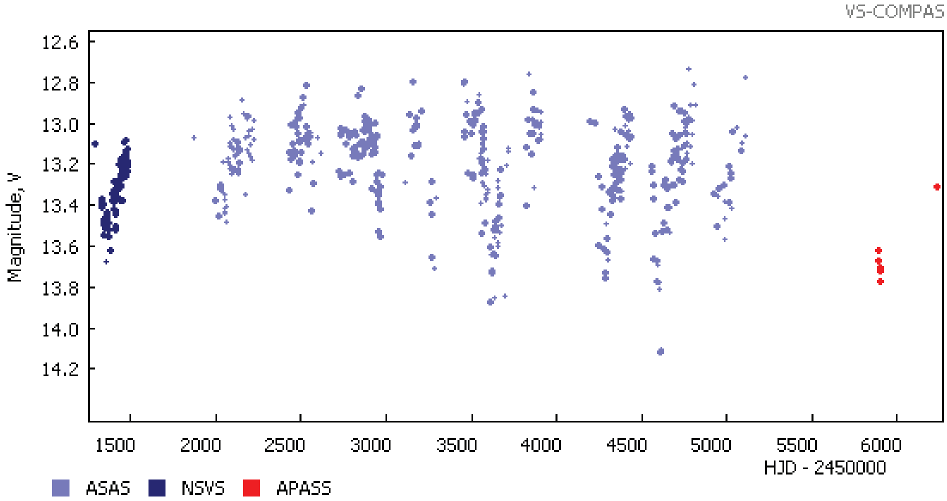


Figure 2. - The light curve of *NSV 13538*, built of the combined photometric data from the ASAS-3, NSVS and the APASS surveys.

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Acknowledgements: This publication has made use of the SIMBAD и VizieR databases operated at the Centre de Donnees Astronomiques (Strasbourg) in France, International Variable Star Index (AAVSO), All Sky Automated Survey (ASAS) and of the Two Micron All Sky Survey (2MASS). In this research there was a custom period search and data analysis software used, created by A.Prokopovich and I.Adamin.

NSVS 11075037 = Dauban V53: updated elements of a Mira variable in Hercules

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Abstract: Refined elements of a Mira variable in the constellation of Hercules are presented in the paper. The variability of NSVS 11075037 was detected in December of 2012 by I. Sergey, based on photometric data from the Northern Sky Variability Survey, as a part of the VS-COMPAS data mining project. Lately, by the time the star's data was finally analyzed in 2013, the object was identified as the Dauban V53 in the VSX catalog, with no period and classification specified. Thus, a revision with up-to-date data was submitted.

During the candidates selection process in the constellation of Hercules as a part of data mining activity performed by the VS-COMPAS project team in December of 2012, the source identified as NSVS 11075037 was considered a variable. The object was not on record in the AAVSO International Variable Star Index (VSX) then.

The photometric data of NSVS 11075037 was analyzed in 2013. By that time the object was submitted to the VSX as a result of the Dauban Survey activity. The Dauban Survey project is a collaboration between Francois Kugel and Jerome Caron (2012).

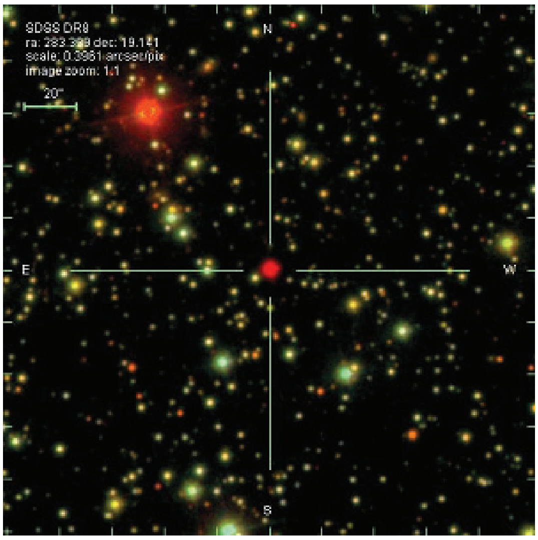

Figure 1. – *NSVS 11075037 and Dauban V53 reference the same object*

The Northern Sky Variability Survey (Woźniak et al., 2004) has a moderate resolution, so there are cases, where the identification remains uncertain, especially in crowded fields. NSVS 11075037 was later cross-identified with the Dauban V53, GSC2.3 N2CN079432 and UCAC4 546-080879, but the corresponding record in the VSX did not contain any information about the epoch, period and classification. The pictures made by the Dauban Survey clearly demonstrate that the variable object in the area, which corresponds to NSVS 11075037, is the only variable source among its neighbors.

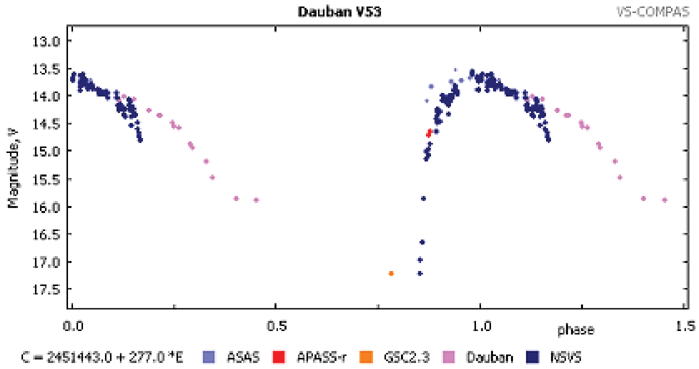

Figure 2. – *Folded light curve for NSVS 11075037. The period is 277 days.*

Detailed analysis was made by Siarhey Hadon in December 2013. Periodogram analysis revealed a peak corresponding to a period of 277 days. This value has a good match with the photometric data points gathered by Kugel and Caron.

The light curve data from the NSVS database was contaminated by several neighboring stars. Deblending of the light curve data allowed to find the real magnitude range. Taking into consideration other properties of the star and its color index, it was classified as a Mira variable. The revision has been submitted to the VSX.

Above, the folded light curve of NSVS 11075037 is presented. The light curve looks interesting and promising (cf. Figure 2), though no data is available for the faint phase around the minima. Further observations are required.

This research has made use of the SIMBAD and VizieR databases operated at the Centre de Données Astronomiques (Strasbourg) in France; of the International Variable Star Index (AAVSO), and of the Two Micron All Sky Survey (2MASS). Period search and analysis software is created by A. Prokopovich and I. Adamin, members of the VS-COMPAS data mining project.

NSVS 11075037 = Dauban V53	
AAVSO UID	306058
Constellation	Hercules
Other Names	2MASS J18533581+1908266 NSVS 11075037 AKARI-IRC-V1 J1853358+190826 IRAS R18514+1904

Coordinates	18 53 35.82 +19 08 26.7 (J2000.0)
Mag. range	13.7 - <17.2 V
Epoch	21 Sep 1999 (HJD 2451443)
Period	277 days
Var. type	M

Remarks

NSVS magnitudes are contaminated by: 2MASS J18533658+1908052 (J-K= 0.62, V= 16.1, sep. 24"), 2MASS J18533529+1907541 (J-K= 0.55, V= 16.9, sep. 33"), 2MASS J18533358+1908131 (J-K= 0.95, V= 16.4, sep. 35"), 2MASS J18533814+1908403 (J-K= 0.49, V= 15.7, sep. 36"), 2MASS J18533709+1907511 (J-K= 0.39, V= 14.3, sep. 40"), 2MASS J18533846 1908464 (J-K= 0.65, V= 14.4, sep. 42"), 2MASS J18533463+1909075 (J-K= 0.72, V= 16.8, sep. 44"), 2MASS J18533510+1909141 (J-K= 0.69, V= 16.3, sep. 49"), 2MASS J18533377+1907467 (J-K= 0.44, V= 14.0, sep. 49") and 2MASS J18533785+1909069 (J-K= 0.54, V= 15.9, sep. 50"). Range has been corrected. J-K= 1.44.

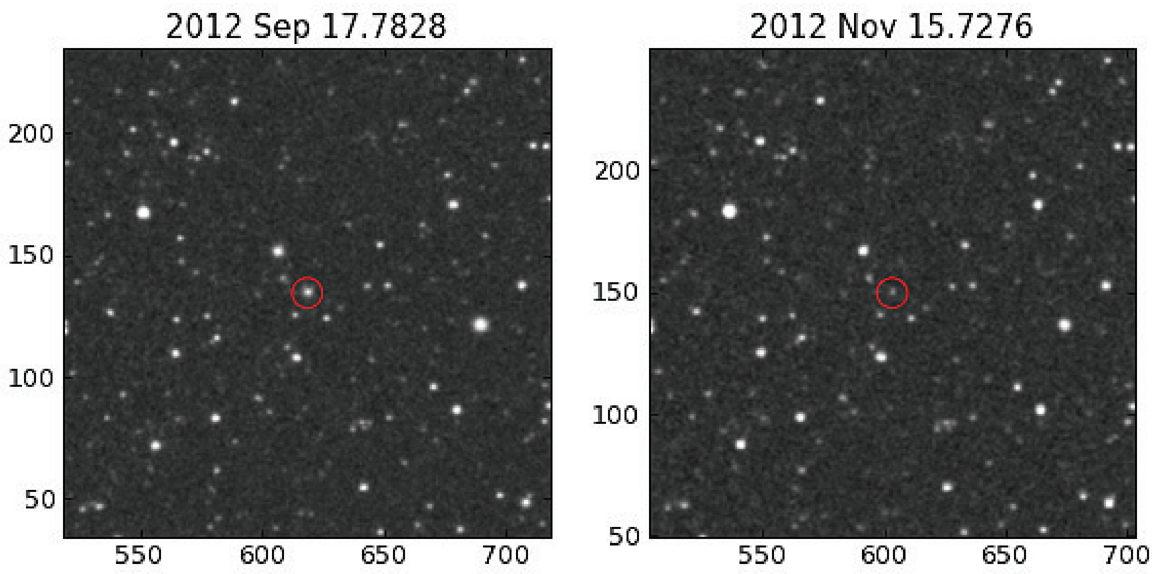

Figure 3. – *Charts proving a variability of Dauban V53.*
Image credit: http://www.aspylib.com/newsurvey/_data/V0053.html

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Updated photometric elements of three variables in Lynx: GSC 03405-00823, GSC 03408-02627 and TYC 3408-00557-1

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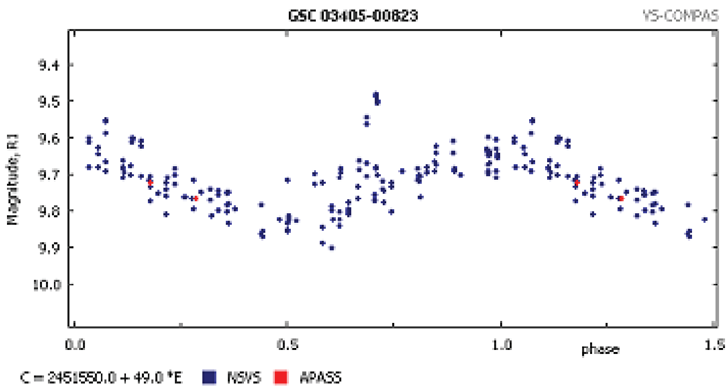
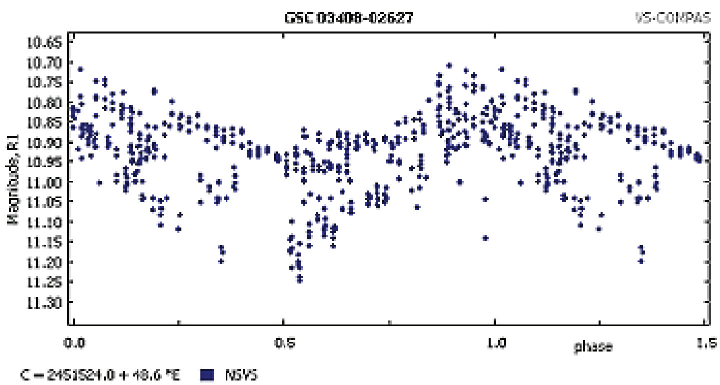
Abstract: The new variable stars published by A. Khruslov (2013; «New Variable Stars II»; Peremennye Zvezdy, Prilozhenie, vol. 13, N 6) have been investigated using data from various public photometric surveys. We confirm the findings listed in the referenced article; additionally, likely periods could be determined for GSC 03405-00823, GSC 03408-02627 and TYC 3408-00557-1, which were not given elements in the original publication due to poor photometric coverage by the NSVS.

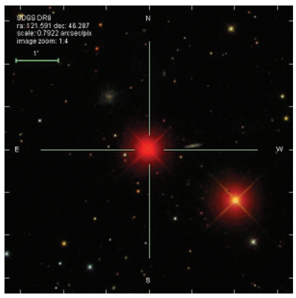
Revised elements of three known variable stars from the article «New Variable Stars II» (Khruslov, 2013) are presented in this article. Period search and analysis was made by Siarhey Hadon using the "VSC Effect" custom software created by A. Prokopovich and I. Adamin. A search for additional data in other sky surveys was performed, but, generally, the Lynx region has poor coverage.

Below possible folded light curves for GSC 03405-00823, GSC 03408-02627 and TYC 3408-00557-1 are shown, based on available data from the NSVS.



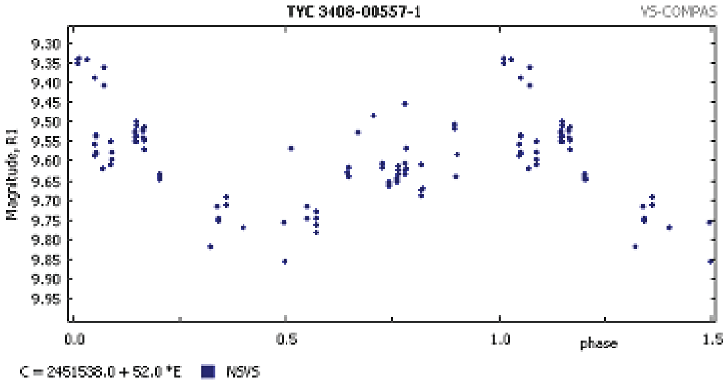
GSC 03405-00823 in Lynx (HJD 2451500-2451600)

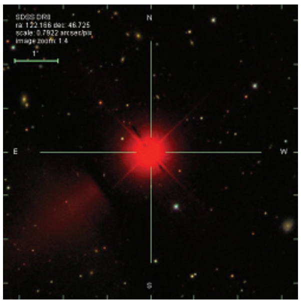




GSC 03408-02627 in Lynx (HJD 2451450-2451600)

The target star is in a crowded area, so the light curve data from the NSVS database was contaminated by the following non-variable neighboring stars: 2MASS J08062516+4617067 (J-K= 0.40, V= 16.2, sep. 33").





TYC 3408-00557-1 in Lynx (HJD 2451500-2451630)

Table 1. – The list of revised variable stars presented in this paper.

Object Designation	RA (J2000)	DEC (J2000)	Var. Type	Epoch, HJD*	Period*	Mag. Range*
GSC 03405-00823	07 27 24.77	+51 28 34.5	SR	2451550	49	9.6 - 9.85 R1
GSC 03408-02627	08 06 22.04	+46 17 15.6	SR	2451524	48.6	10.75 - 10.95 R1
TYC 3408-00557-1	08 08 39.90	+46 43 28.8	SR	2451538	52	9.35 - 9.8 R1

* elements are valid for the selected date ranges

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Authors wanted!

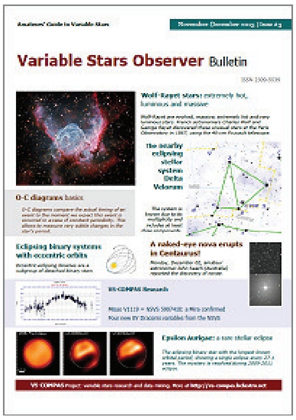
We invite authors and amateur researchers to publish their articles in the Variable Stars Observer Bulletin. If variable stars are your passion and you have something interesting to say to the community – go ahead and contribute! No matter whether your article is a strict scientific text reporting your advanced research results or just an overview article for amateur reading – it works. Amateur astronomy has a good commitment to the science for generations, and there is always a need for a good read for people who are just on their way to the big science. Or just want to be in the context of contemporary progress in astronomy.

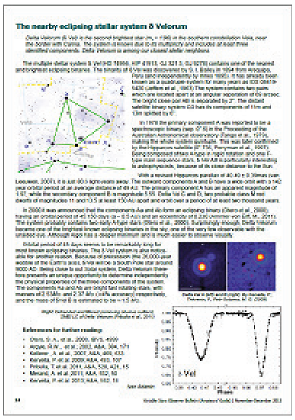
Pure scientific texts often require a solid background in math and astrophysics, but what we can do is to create a simplified overview of those papers. This intention follows a very clear goal: to provide a simple join-point for amateurs to advanced scientific research, taking into account their basic experience. For those who are interested in further reading, there are always lists of recommended publications or web references to continue with.

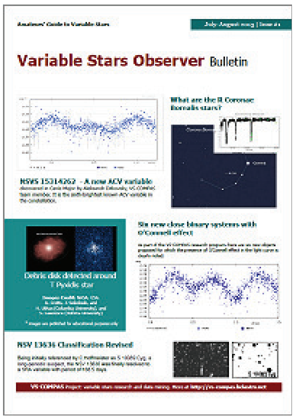
Authors making research in the field of variable stars are welcome to publish their articles in the following issues! Should you have an article ready for sharing with the community, just contact us, so we can schedule it.

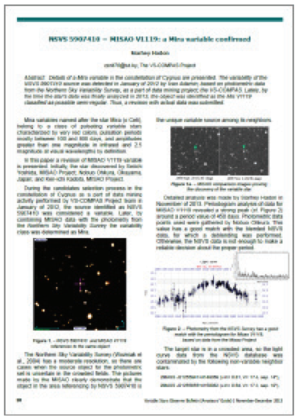
So far, we have prepared five issues, so everyone can check out the overall concept behind the project. Do not hesitate to forward your questions to vs-compas@belastro.net.

Clear skies!









The VS-COMPAS Project

The project was started in fall of 2011 by four amateur astronomers from Belarus. The main intention is to expand the International Variable Star Index (VSX) catalog with new variable stars, variable stars data analysis and research. Among the most significant achievements it is worth to mention more than 1200 variable stars discovered by combined efforts of seven active team members. All data about discovered stars is submitted to the VSX catalog running by the AAVSO. Another valuable goal the project has is increasing public interest to variable stars science.

More information about the team and discoveries can be found at http://vs-compas.belastro.net