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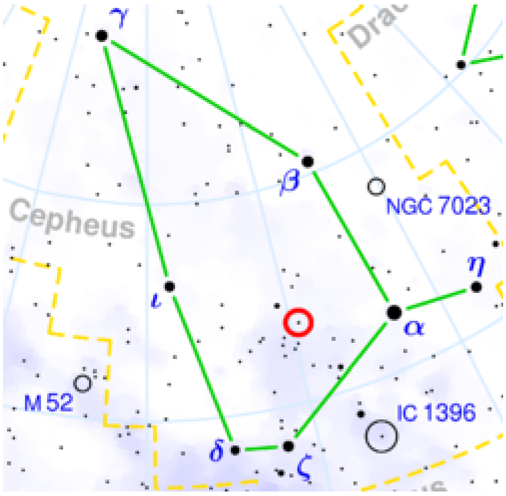

VV Cephei: an extraordinary binary system

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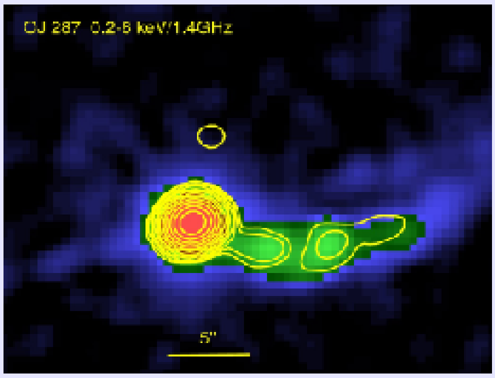
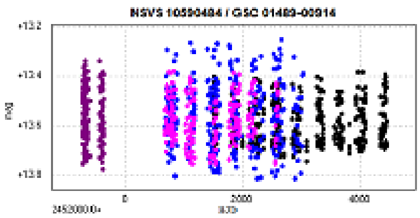


Discovery of a Second Radial Mode in the High Amplitude Delta Scuti Star NSVS 10590484



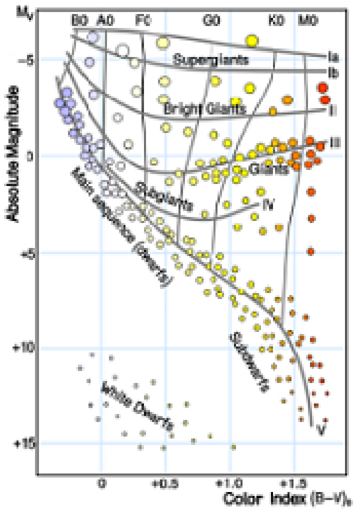
NSVS 10590484 is an HADS(B) star with the following elements: P0= 0.0541911 d; P1= 0.0419105 d

Notable long-period eclipsing binaries. Part I.

Long-period eclipsing binary stars offer the chance to study the characteristics of isolated stars with a high degree of precision and accuracy.

Pulsating variable stars and the H-R diagram

Studying intrinsically pulsating variable stars plays a very important role in the understanding of stellar evolution .



Stellar associations: a variable stars nursery

The study of stellar associations and star formation regions is an important activity in the research of stellar evolution and systems.

Variable Stars Observer Bulletin
Amateurs' Guide to Variable Stars

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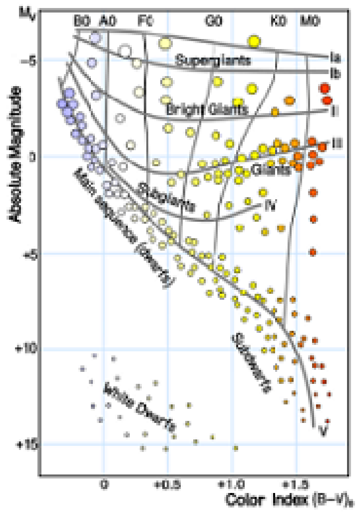
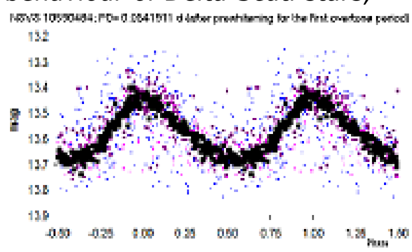
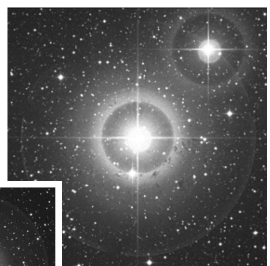






BL Lacertae objects - Blazars

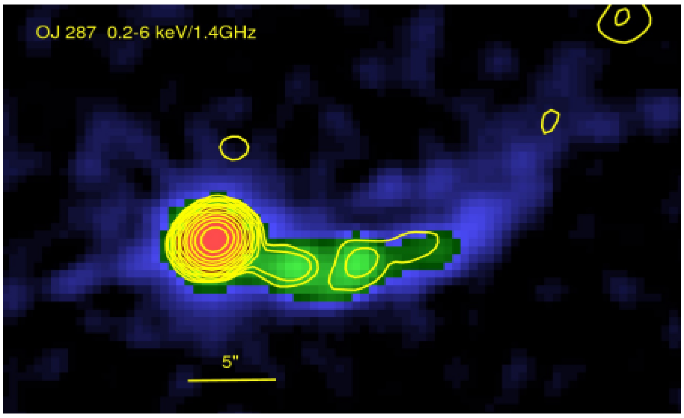
BL Lacertae objects demonstrate the most violent behavior known among active galactic nuclei (AGN). These objects are mostly notable for being strongly and rapidly variable at all wavelengths, displaying substantial variations in brightness over a short period of time. Their properties also include high optical polarization and the lack of optical emission lines. They are named after the prototype object BL Lacertae, located in the constellation Lacerta (the Lizard), which was initially believed to be a variable star in our galaxy.

Being discovered as a high-amplitude variable star (Hoffmeister, 1929), BL Lacertae was originally thought to be an irregular variable star in the Milky Way galaxy, and thus was given a variable star designation. In 1968, John Schmitt at the David Dunlap Observatory matched BL Lacertae with a bright variable radio source VRO 42.22.01 (MacLeod & Andrew, 1968). A faint trace of a host galaxy was also found. In 1974, Oke and Gunn measured the redshift of BL Lacertae as z = 0.07, corresponding to a recession velocity of 21,000 km/s with respect to the Milky Way (Kinman, 1975).

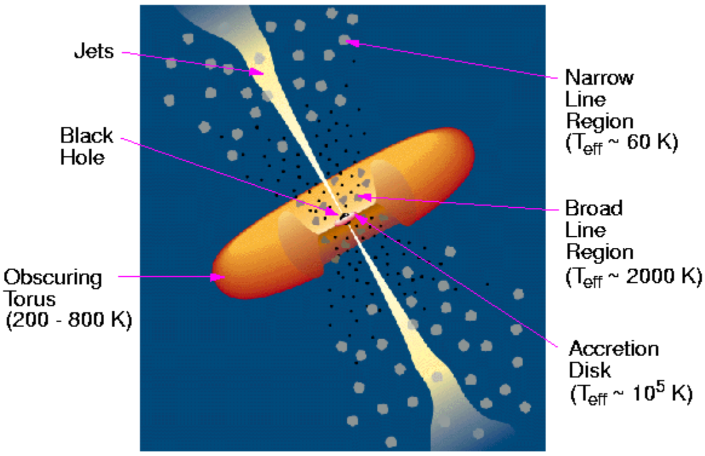
BL Lacertae objects, abbreviated BL Lac, are a rare type of Active Galactic Nuclei(AGN), the extremely energetic nuclei of active galaxies. Roughly 40 BL Lac objects are known. Perhaps the most obvious property of BL Lac objects is that they are quasi-stellar, but very distant active galactic nuclei in fact. The light from BL Lacertae is dominated by non-thermal emissions. There are different types of BL Lacs, depending on the wavelength they are brightest at (radio or X-ray domain). In many cases they have been identified with radio sources. BL Lacs are observationally distinguished primarily by the absence of strong emission lines (Stein et al. 1976) and mainly known as the largest population of emitters in gamma-ray band. Thus, their redshifts can only be determined from features in the spectra of their host galaxies.

An active galactic nucleus (AGN) is a compact region at the centre of a galaxy which has a much higher than normal luminosity. A galaxy hosting an AGN is called an active galaxy. The radiation from AGNs is believed to be a result of accretion onto the supermassive object at the centre of the host galaxy. AGNs are both compact and extremely luminous. AGN terminology is often confusing, but it is reasonable to divide those objects into two classes, depending on their radio activity.

*Below: **BL Lac object OJ287**, at a redshift of 0.306 (distance of 5.15 billion light-years), so that 1" corresponds to 15,000 light-years False color: X-ray image from the Chandra X-ray Observatory - **http://cxc.harvard.edu/**; contours: 1.4 GHz radio image from the Very Large Array - **http://www.nrao.edu/vla***



AGN Unification
(Diagram from Urry & Padovani 1995)



A schematic diagram of the current paradigm for radio-loud AGNs (Urry & Padovani, 1995)

New members to the AGN family was added in the late 1970s, with the identification of a few outstanding objects from variable star catalogs as highly variable nuclei of distant galaxies.

By 1968, the first two objects were identified: BW Tauri (3C 120) and BL Lacertae. In 1965 Arp and Burbidge found that the object called 3C 120, a radio source detected at Cambridge in 1959, is a Seyfert galaxy - another kind of active galaxies. Later, in 1971, AP Librae and W Comae Berenices (ON 231, which changes by 6 magnitudes - the largest known amplitude for blazars) were identified as remote BL Lacertae objects.

Blazars appear to be, in fact, very similar to Seyfert galaxies, except that blazars tend to be elliptical galaxies and Seyferts tend to be spiral galaxies. Seyfert galaxies belong to radio-quiet AGN class, while Blazars show strong radio and X-ray emission.

An interesting fact: it took 59 years until the extragalactic nature of the "variable star" X Com, discovered in 1914 by Wolf, was proven (Steinicke, 2000). By 1976, there were 30 known objects (Stein, 1976).

Yale Fermi/SMARTS *(Small and Moderate Aperture Research Telescope System) project's monitoring programs of Optical/IR Observations of LAT Monitored Blazars include a wide list of targets. The SMARTS Consortium operates four small telescopes (1.5-m, 1.3-m, 1.0-m and 0.9-m) on Cerro Tololo Inter-American Observatory (Chile) for that purpose. Membership in SMARTS is open to individuals or institutions, including international partners. Web: www.astro.yale.edu/smarts*

The list of targets is available at: ***http://www.astro.yale.edu/smarts/glast/targets.html***

Fermi Gamma-ray Space Telescope *was launched from the Kennedy Space Center on June 11, 2008. The Fermi spacecraft supports two gamma-ray instruments: the Large Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM).*

Image Credit: NASA

The ***Fermi-LAT*** is a wide-field gamma-ray telescope, while the GBM is an all-sky monitor for transient events detection, such as occultations and gamma-ray bursts. Fermi-LAT can be used for detection of gamma-ray activity of BL Lacertae objects. The Fermi science data (along with the software to analyze it) is available at the Fermi Science Support Center portal at http://fermi.gsfc.nasa.gov/ssc/data

The term "blazar" was coined in 1978 by astronomer Edward Spiegel. At the end of the seventies the use of modern detectors (CCD) allowed observers to probe with better accuracy the nature of the nebulosity. First images of the BL Lac object PKS 0548-322 taken by M. Disney in 1974 found it to be composed by a giant elliptical galaxy with a bright nucleus, with their jets pointed straight at us. We now believe that the source of the energetic emissions from blazars, or BL Lacertae Objects (as they are often called), is a super-massive object at the center of the galaxy.

Unlike most stars, BL Lac objects are very strong sources of radio and infrared emission. This emission, which is called synchrotron emission, arises from electrons traveling near the speed of light in spiral paths in strong magnetic fields. Synchrotron emission is generally polarized. When light or other electromagnetic radiation is polarized, the directions of the oscillations are the same. The amount of polarization and the brightness of BL Lac objects is highly variable. This variability is usually very rapid and irregular: they can change significantly in 24 hours or less. The rapid variability tells us that the energy source is small. It is considered that in the BL Lacs the relativistic jet is closely aligned to the line of sight (less than 20 degrees) and relativistic effects play an important role in the observed properties of the BL Lacs (Blandford & Rees 1978).

Blazar - broader term including *BL Lacertae* objects and those quasars, which share their characteristics of unusually weak spectral features, along with strong and rapid variability, so-called Optically Violent Variables (OVVs). Blazars are some of the most energetic objects in the Universe. At the other hand, they are all so called quasi-stellar objects (QSO), with large red shifts.

Currently, the most extensive list of the BL Lacertae objects is presented in the *Roma-BZCAT catalogue* of 2700 radio/optical blazar-like sources, by Massaro et al. (2009). This catalog is based on multifrequency surveys and detailed checkout of the literature, and contains 1180 BL Lacertae objects and candidates. But only a relatively small number of objects have been observed intensively at many wavelengths simultaneously. The spectral coverage of many of them is poor, both in time and in frequency. Generally, BL Lacs have been discovered in either radio or X-ray band. That forms the base of their classification as radio-selected (RBL) and X-ray-selected (XBL) BL Lacs. There are three BL Lac subclasses: HBL, IBL and LBL. The difference between them is the peak frequency of the synchrotron component of their spectral energy distribution (SED). HBLs have high-energy peaks, LBLs - low-energy peaks, IBLs - intermediate (Nieppola et al., 2006).

Being equipped with modern CCD cameras, amateurs are also able to monitor apparent changes in brightness of AGNs (including blazars, of course) and alert professional astronomers about their unusual activity. There are several catalogs out there for targets selection.

Below several useful catalogs for blazar-like targets selection are listed:

Optically selected BL Lac objects from SDSS-DR7 (Plotkin et al., 2010)
http://cdsarc.u-strasbg.fr/viz-bin/Cat?cat=J/AJ/139/390

A Sample-oriented Catalogue of BL Lacertae Objects (Padovani & Giommi, 1995). A catalogue of 233 BL Lacertae objects compiled through an extensive bibliographic search updated to mid-1995 is presented.
http://www.eso.org/~ppadovan/catalogue.html (many listed as candidates)
http://ned.ipac.caltech.edu/level5/Padovani/Padovani_contents.html

BL Lacertae objects beyond redshift 1.3 - UV-to-NIR photometry for Fermi/LAT blazars (Rau et al., 2013)
http://cdsarc.u-strasbg.fr/viz-bin/Cat?J/A+A/538/A26

BL Lac candidates for TeV observations (Massaro et al., 2013)
http://cdsarc.u-strasbg.fr/viz-bin/Cat?J/ApJS/207/16

A spectroscopic Library of BL Lac objects (Sbarufatti et al., 2005)
http://archive.oapd.inaf.it/zbllac/index.html

The Second Catalog of Active Galactic Nuclei detected by the Fermi Large Area Telescope, comprising 395 BL Lacertae objects (Ackermann et al., 2011) - http://cdsarc.u-strasbg.fr/viz-bin/Cat?J/ApJ/743/171

NASA/IPAC Extragalactic Database (NED), which is operated by the Jet Propulsion Laboratory
http://ned.ipac.caltech.edu/

Useful monitoring projects conducting photometric measurements of quasars:

MOJAVE (Monitoring Of Jets in Active galactic nuclei with VLBA Experiments) is a long-term program to monitor radio brightness and polarization variations in jets associated with active galaxies visible in the northern sky. At their website there is a list which contains all blazars known to be regularly monitored:
http://www.physics.purdue.edu/MOJAVE/blazarlist.htm

HQM - Hamburg Quasar Monitoring

The Hamburg Quasar Monitoring Programm (HQM) has been performed between 1988 and 1995. Later follow-up observations in 1996, 1998, 2000 and 2001 as well as some earlier data between 1984 and 1986 from previous projects enlarged the overall sample time for some of our targets up to 15 years. The HQM sample contains lightcurves for roughly 500 quasars, in total about 35.000 individual datapoints, although the main target list is much shorter - around 300 targets.

http://www.friedensblitz.de/hqm/hqm-home.html

FQM - Frankfurt Quasar Monitoring

The Frankfurt Quasar Monitoring Project is a privately run observing program by Stefan Karge (Frankfurt, Germany), focusing on photometric measurements of quasars, BL Lac objects and selected AGNs. Since the beginning of this observing program in 1998, some 5800 observations have been recorded for about 400 quasi-stellar objects. A selection of particularly interesting objects is presented there: objects data, detailed finding charts, *including comparison stars*(!), light curve data and notes.

http://quasar.square7.ch/fqm/fqm-home.html

Hamburg-Quasar-Monitoring (1988 — 1998 data)
http://www.hs.uni-hamburg.de/DE/Ins/Per/Refsdal/jschramm/hqm98/hqm-titel.html

Mrk 501

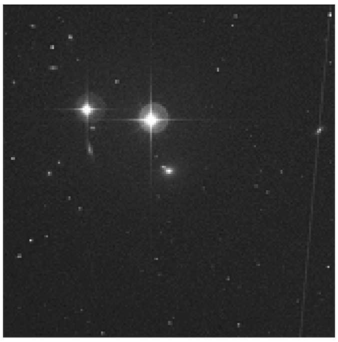
3C 371

BL Lacertae

1ES 1959+650

OQ 530

S5 0716+71



Mrk 421

OJ 287

BL Lacertae objects considered for monitoring using moderate apertures

Object Designation		Const.	RA (J2000)	DEC (J2000)	z	Mpc	Mag. Range
3C 66A	PKS 0219+428	And	02 22 39.6	+43 02 08	0.444	1647	12.81-16.56
PKS 0422+00	TXS 0422+004	Tau	04 24 46.8	+00 36 07	0.310	– –	13.65-17.0
S5 0716+71	EGRET J0720+71	Cam	07 21 53.3	+71 20 36	0.310	1154	12.40 - 15.3 V
OJ 287	PKS 0851+202	Cnc	08 54 48.8	+20 06 30	0.306	1178	12.0 - 17.5
Mrk 421	OM+303	UMa	11 04 27.2	+38 12 32	0.031	126	11.6 - 16.5
W Com	LINEAR 3472523	Com	12 21 31.7	+28 13 58	0.102	414	11.5 - 17.5 B
AU CVn	B2 1308+32	CVn	13 10 28.7	+32 20 44	0.997	3221	14.2 - 20 B
OQ 530	PG 1418+546	Boo	14 19 46.6	+54 23 14	0.152	617	10.8 - 16.5
AP Lib	PKS 1514-24	Lib	15 17 41.8	- 24 22 20	0.048	243	14 - 16.7 B
Mrk 501	OS+387	Her	16 53 52.2	+39 45 37	0.033	137	13.2 - 14.0 V
3C 371	UGC 11130	Dra	18 06 50.7	+69 49 28	0.050	233	13.5 - 15.4
1ES 1959+650	TXS 1959+650	Dra	19 59 59.9	+65 08 55	0.047	250	12.8 - 16
PKS 2155-30	TXS 2155-304	PsA	21 58 52.0	-30 13 32	0.116	462	12.0 - 14.1
BL Lac	PKS 2200+420	Lac	22 02 43.3	+42 16 39	0.069	274	12.4 - 17.2 B
3C 454.3	PKS 2251+158	Peg	22 53 57.7	+16 08 53	0.859	2871	12.3 - 17.2

Suspected BL Lacs: *NSV 21875, NSV 477, NSV 16877* (very faint)

The article would be incomplete without mentioning of the next two useful resources:

- Extragalactic Objects Discovered As Variable Stars (Wolfgang Steinicke, 2000)
  http://www.klima-luft.de/steinicke/AGN/vargal/vargal2000.htm
- Bruce Gary's list of blazars compiled from AAVSO data, which will be useful for amateur observers.
  http://brucegary.net/blazar

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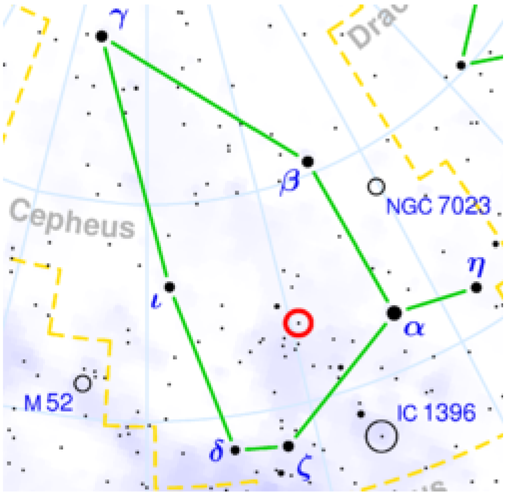
Ivan Adamin

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).

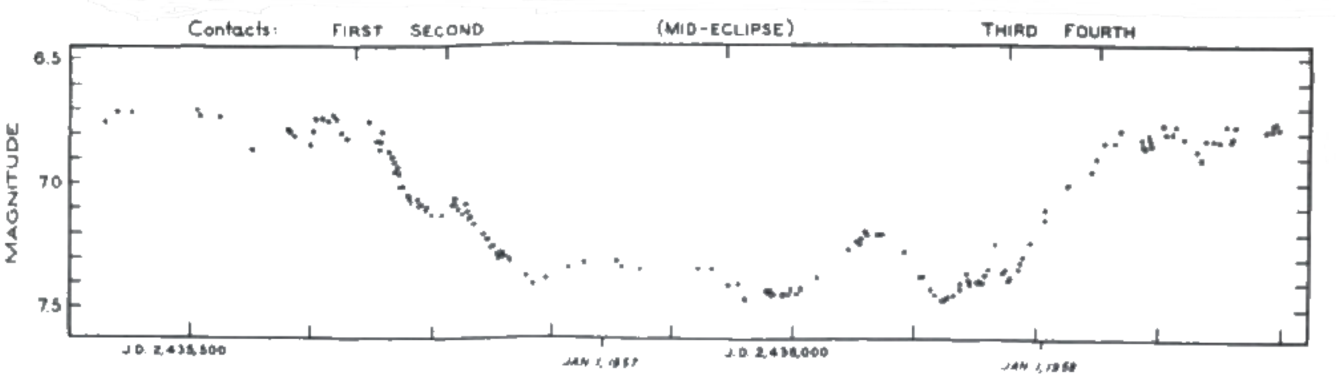
There is evidence of matter accretion from the primary star A onto the blue companion for at least part of the orbit. VV Cephei A (red) is not entirely spherical, being surrounded by a highly extended atmosphere. The red component has one of the biggest diameters ever measured at a star: the angular 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).



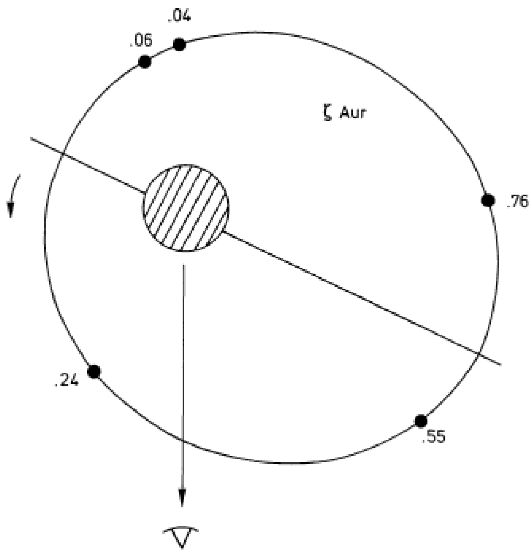
Historical light curve of VV Cephei during the eclipse of 1956-1958. Photoelectric measurements were made in blue light by G. Larsson-Leander. The light curve in the minimum is not flat, as might be expected, and shows waves due to intrinsic variations of the red supergiant component. The diagram was 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).*

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Ivan Adamin

Pulsating variable stars and the Hertzsprung-Russell diagram

Studying intrinsically pulsating variable stars plays a very important role in stellar evolution understanding. The Hertzsprung-Russell diagram is a powerful tool to track which stage of stellar life is represented by a particular type of variable stars. Let's see what major pulsating variable star types are and learn about their place on the H-R diagram. This approach is very useful, as it also allows to make a decision about a variability type of a star for which the properties are known partially.

The Hertzsprung-Russell diagram shows a group of stars in different stages of their evolution. It is a plot showing a relationship between luminosity (or absolute magnitude) and stars' surface temperature (or spectral type). The bottom scale is ranging from high-temperature blue-white stars (left side of the diagram) to low-temperature red stars (right side). The position of a star on the diagram provides information about its present stage and its mass. Stars that burn hydrogen into helium lie on the diagonal branch, the so-called main sequence.

In this article intrinsically pulsating variables are covered, showing their place on the H-R diagram.

Pulsating variable stars form a broad and diverse class of objects showing the changes in brightness over a wide range of periods and magnitudes. Pulsations are generally split into two types: radial and non-radial. Radial pulsations mean the entire star expands and shrinks as a whole, while non-radial ones correspond to expanding of one part of a star and shrinking the other. Since the H-R diagram represents the color-luminosity relation, it is fairly easy to identify not only the effective temperature and absolute magnitude of stars, but the evolutionary component of their development stage as well.

According to the concept, stars plotted in the upper left corner of the chart will be the brightest ones with the highest surface temperature, therefore, according to the evolutionary status, they must be very young. Top right part contains cool and bright supergiants. Bottom part of the H-R diagram represents dwarf stars, which are in a very late evolutionary state: left size for hot dwarfs and the opposite – for cool brown dwarfs.

H-R diagram

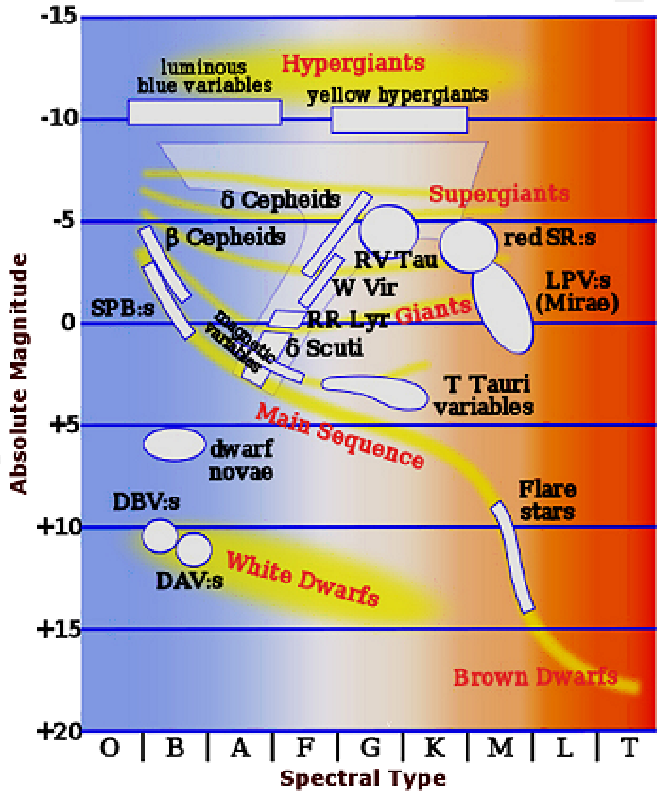
Stars are classified into seven main luminosity classes.

Supergiants (I)

Very massive and luminous stars near the end of their lives. They are subclassified as Ia or Ib, with Ia representing the brightest of these stars. The nearest supergiant star is Canopus (F0Ib), about 310 light years away. Some other examples are Betelgeuse (M2Ib), Antares (M1Ib) and Rigel (B8Ia).

Bright giants (II)

Stars which have a luminosity between the giant and



Intrinsic variable types on the Hertzsprung–Russell diagram. Image credit: Wikipedia

supergiant stars. Some examples are Sargas (F1II) and Alphard (K3II).

Giants (III)

These are mainly low-mass stars at the end of their lives that have swelled to become giant stars. This category also includes some high-mass stars evolving on their way to supergiant status. Some examples are Arcturus (K2III), Hadar (B1III) and Aldebaran (K5III).

Subgiants (IV)

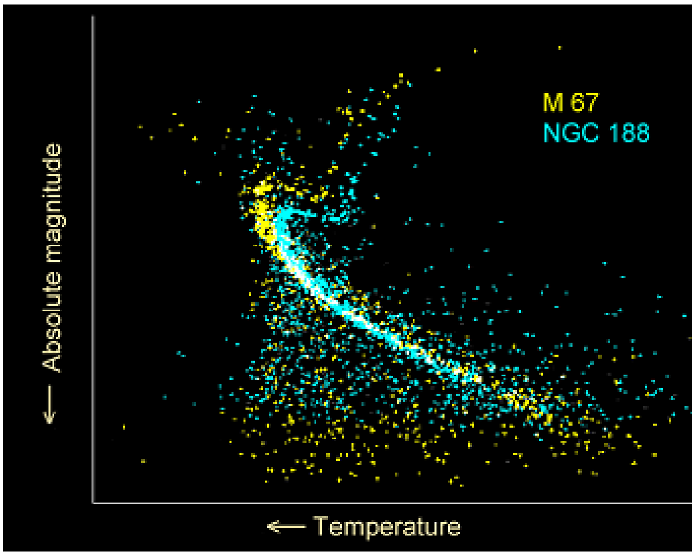
Stars which have begun evolving to giant or supergiant status. A subgiant star is a star that is slightly brighter than a normal main-sequence (dwarf) star of the same spectral class. Some examples are Alnair (B7IV) and Muphrid (G0IV). Note also the Procyon, which is entering this category and therefore is F5IV-V.

Main sequence (V)

All normal hydrogen-burning stars. Stars spend most of their lives in this category before evolving up the scale. Class O and B stars in this category are actually very bright and luminous and generally brighter than most giant stars. Some examples are the Sun (G2V), Sirius (A1V), and Vega (A0V).

Subdwarfs (VI) and White Dwarfs (VII)

The *Yerkes spectral classification* distinguishes two additional classes - for subdwarfs and white dwarfs. On an Hertzsprung–Russell diagram subdwarfs appear to lie below the main sequence. White dwarfs are thought to represent the end point of stellar evolution for main-sequence stars with masses from about 0.07 to 10 solar masses.



H-R diagram for two open clusters (M67 and NGC 188), showing the main sequence turn-off at different ages. Image credit: Wikipedia

The ***Instability Strip*** is a region on the H-R Diagram in which many variable stars can be found. This strip extends through the A, F, and occasionally G classes above and below the main sequence. In this strip, stars have a tendency to be unstable and pulsate, thus causing them to have some variability.

Below is a brief overview of the most commonly encountered pulsating variables types, with their typical properties and representatives.

α **Cygni (ACYG)**

Alpha Cygni variables are a type of rare blue supergiant pulsating variable stars that undergo non-radial pulsations, typically with a period of 5 to 10 days. The spectral types are Bep to Aep Ia, and the optical amplitude is of the order of 0.1 mag. They are often referred to as luminous blue variables (LBV) and occupy the top left part of the H-R diagram. Variable stars of this type are sometimes called S Doradus variables, and there are reasons to assume these variables represent the next stage of evolution of S Dor stars.

The light variations often appear irregular, being caused by the superposition of multiple pulsation frequencies with close periods. Cycles from several days to several weeks are observed. The prototype of these stars, Deneb (α Cygni), exhibits fluctuations in brightness between magnitudes +1.21 and +1.29.

Typical examples: α Cyg, ρ Leo, β Ori, η Ori, PX Gem, κ Cas, η CMa.

β **Cephei** or β **Canis Majoris (BCEP)**

Beta Cephei are short-period variable stars of O8-B6 I-V spectral types, which exhibit variations in their brightness due to radial pulsations of the stars' surfaces. These variables lie slightly above the upper main sequence and have typical periods between 0.1 and 0.6 days, and their brightness varies from 0.01 to 0.3 mag. They are particularly interesting because the nature and cause of their pulsations are totally unknown. Maximum brightness corresponds to the minimum radius of the star. For several stars there are indications of non-radial pulsations though, like for β Cen, 53 Per/V469 Per.

Typical examples: β Cep, β Cen, β CMa, δ Cet, α Lup, KP Per, η Hya, ε Per.

δ **Scuti (DSCT)**

Delta Scuti variables are a well-known type of pulsating variable belonging to the main sequence. This type of stars is notable for a very short period, lasts for hours. Typically, periods are in the range of 0.02-0.4 days. Brightness varies between 0.02m and 0.8m.

These variables are important standard candles and have been used to establish the distance to numerous globular and open clusters, as they follow a period-luminosity relation in certain passbands. Spectral class can be A2 to F5 III-V. The recently discovered rapidly oscillating main-sequence Ap stars are also a subclass of Delta Scuti variables. Both radial and non-radial pulsations are observed for Delta Scuti stars.

Typical examples: δ Sct, DQ Cep, GG Vir, δ Del, OX Aur, DY Her, YZ Boo, V703 Sco

δ **Cephei (DCEP)**

Classical Cepheids (or Delta Cephei variables) are population I yellow supergiants which undergo pulsations with very regular periods on the order of days to months.

Radially pulsating, Cepheid variables change their brightness with periods from 1 to 135 days, with amplitudes of 0.1 to 2.0 magnitudes in V. These massive stars have high luminosity and are of F spectral class at maximum, and G to K at minimum. The later the spectral class of a Cepheid, the longer it takes to complete a cycle. This mainly depends on the metallicity of the star, which divides them into Population I and Population II. Population I stars are generally found closer to the galactic plane, often in open clusters. They have relatively high concentrations of metals, compared to Population II stars (W Virginis), which are found around the galactic halo and in globular clusters.

Classical Cepheids are relatively young stars, and lie at the intersection of the instability strip with the supergiant branch in metal-rich stars. They are also famous due to a period-luminosity relationship (δ Cep, η Aql, l Car).

There is also a DCEPS subtype, characterized by amplitudes less than 0.5m in V and almost symmetrical light curves (rise duration is 40-50%). Periods usually do not exceed 7 days, except for a couple of objects with periods of 8 to 13 days. Presumably, this type of stars pulsate in the first overtone and crossing the instability strip on the H-R diagram for the first time (e.g. *SU Cas*) .

Typical examples: δ Cep, RT Aur, X Cyg, η Aql, U Aql, W Gem, T Mon, Z Lac, S Sge, T Vul.

W Virginis (CW)

Oppositely to the Classical cepheids, W Virginis stars lie at the intersection of the strip with the supergiant branch in metal-poor stars. These are pulsating variables of the galactic spherical component population with periods of approximately 0.8 to 35 days and amplitudes from 0.3 to 1.2 mag in V. Type II Cepheids are population II stars and thus are old - typically metal-poor, low-mass objects. They were historically called W Virginis variables.

W Vir variables are present in globular clusters and at high galactic latitudes. They may be separated into the following subtypes:

- **CWA** - periods longer than 8 days (W Vir, RU Cam);
- **CWB** - periods shorter than 8 days (BL Her, AU Peg, VY Pyx).

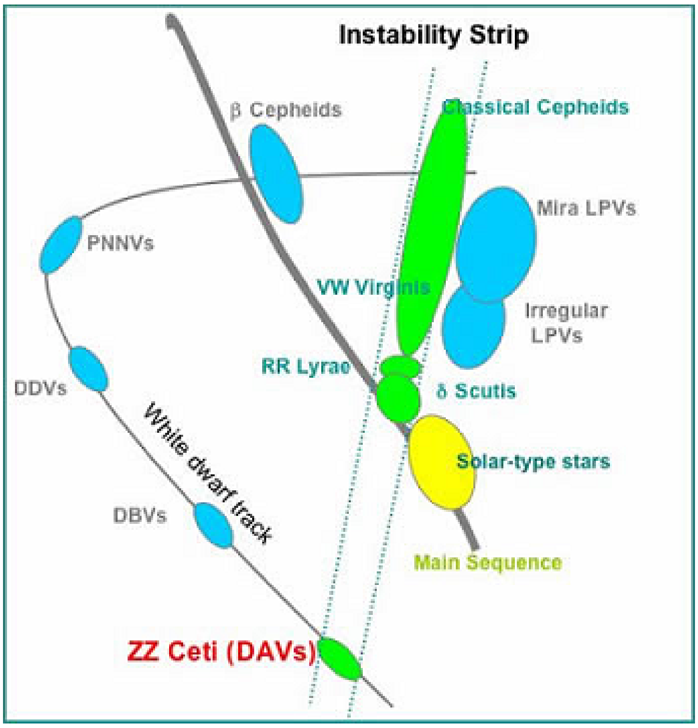
Some DCEP and CW stars are quite often called Cepheids because it is often impossible to discriminate between them on the basis of the light curves for periods in the range 3 - 10 days. Having the same period, CWs are 0.7-2.0m dimmer, comparing to DCEP. A common case is humps on the descending branch, sometimes growing into a flat maximum.

Typical examples: W Vir, RU Cam, κ Pav, BL Her, VY Pyx, TX Del, V0553 Cen, UY CMa.

RR Lyrae (RR)

RR Lyrae variables are old, low-mass, radially pulsating stars with periods in the range between 0.2 and 1 day, which are located where the instability strip intersects the horizontal branch in globular clusters. These are giants of A to F spectral types, and are sometimes referred to as *dwarf Cepheids*. Despite their high abundance in globular clusters, there are many RR Lyrae stars discovered in the galactic plane as well. Initially, they were classified (Bailey, 1902) into three classes - RRa, RRb and RRc – based upon the amplitude and skewness of the light curves. Later, RRa and RRb were merged into a single type – RRab.

RRab stars change their brightness between 0.1m and 0.3m in V-band with periods 0.35 to 1.0 days (e.g. RR Lyr). Variables of the RRc class have amplitudes of about 0.5m, but shorter periods (5-10 hours) and higher light curve symmetry (typically, the rise duration is 40-50%, e.g SX UMa).

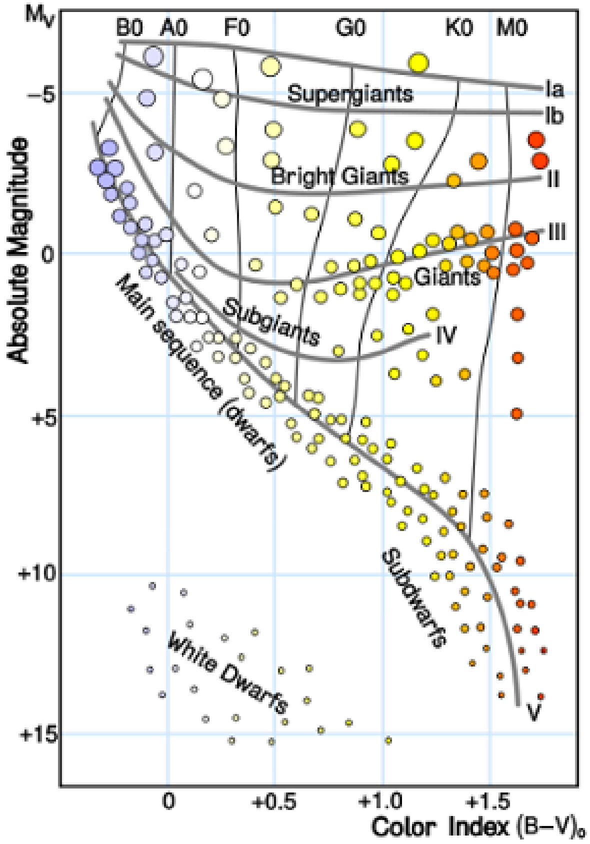


The Instability strip in relation to various types of stars. Cepheids, RR Lyrae, W Virginis, and ZZ Ceti stars can all be found in this region, as well as other, less common variable stars. Image is used for education purpose only. Credit: http://astronomy.swin.edu.au (Swinburne University of Technology)

From the point of stellar evolution, RR Lyrae variables are instability strip pulsators. Their place on the H-R diagram can be easily found as an intersection between the horizontal branch and the instability strip. It appears that RRab stars pulsate in the fundamental frequency of radial pulsations, while RRc variables pulsate in the first overtone. In addition, these types of stars are different from others due to the presence of Blazhko effect.

There is also the RRd subclass for RR variables, characterized by the presence of two simultaneously operating pulsation modes - the primary P0 and the first overtone period P1. Typically, the ratio R1/R0 ≈ 0.745 (e.g. AQ Leo, Z Gru).

Typical examples: RR Lyr, V0764 Mon, SW And, RS Boo, RZ Cep, X Ari, U Lep.



The Hertzsprung–Russell diagram relates stellar classification with absolute magnitude, luminosity, and surface temperature. Image credit: Wikipedia

PV Telescopii (PVTEL)

This class of variables is defined in GCVS as "helium supergiant Bp stars with weak hydrogen lines and enhanced lines of He and C". That is, the hydrogen spectral lines of these stars are weaker than normal for a star of stellar class B, while the lines of helium and carbon are stronger. The PV Tel stars are extremely hydrogen-deficient compared to other B-class stars and vary in luminosity on time scales ranging from a few hours to several years.

Typical examples: PV Tel, FQ Aqr, V1920 Cyg, DN Leo, V2076 Oph.

RV Tauri (RV)

Variables of the RV Tauri type are radially pulsating supergiants having spectral types F-G at maximum light and K-M at minimum. The light curves are characterized by the presence of double waves with alternating deep and shallow minima that can vary in depth. The primary minimum may become secondary and vice versa. The complete light amplitude may reach 3-4 mag in V. Periods between two adjacent primary minima (usually called formal periods) lie in the range 30-150 days.

On the H-R diagram, RV Tau variables ranks between Cepheids, Miras and red semi-regular variables. Since the transition from the AGB to the white dwarf stage of stellar evolution is not fully understood, RV Tau stars are considered as a potential bridge across this evolutionary gap. This post-AGB phase of stellar evolution lasts only a few thousand years. Two subtypes, RVA and RVB, are recognized:

- **RVA -** RV Tauri variables that do not vary in mean magnitude (AC Her);
- **RVB -** RV Tauri variables that periodically (with periods from 600 to 1500 days and amplitudes up to 2 mag in V) vary in mean magnitude (DF Cyg, RV Tau).

Typical examples: R Sct, U Mon, AC Her, V Vul, R Sge, TX Oph, RV Tau, UZ Oph, TW Cam.

Long-Periodic Variables (LPV)

Variability, caused by pulsations, appears to be a fundamental characteristic of cool giant luminous stars. LPVs form a very diverse group of stars. Typical periods are months-long, or even a couple of years. Long-period variables may have spectral class F and cooler, but most are red giants and AGB-giants, meaning spectral class M, S or C. They are usually deep orange or red.

The GCVS distinguishes four classes of red semi-regular variables: SRa, SRb, SRc and SRd. The major difference between the SRa class and the Miras is that an SRa may have a visual light amplitude less than 2.5 magnitudes.

Miras are long-period variable stars belonging to the class of asymptotic giant branch (AGB) stars the (e.g. o Cet, χ Cyg). Their periods are in the range of 80 to 1000 days, and the amplitude of light variations is from 2.5m (by definition) to 11m. Mira variables belong to the late spectral types with emission spectrum - Me, Ce, Se. Their study is very important, as it allows to shed some light on the future fate of Sun-like stars, with masses up to a few solar.

SR is a vast group of pulsating AGB-stars of late spectral types (W Hya, RV Boo). In most cases, periods are from 20 to 2300 days. An *SRs* class has been introduced recently to mark those red giants with periods less than 30 days, like EL Psc. Presumably, these stars pulsate in higher overtones. One of the best known red supergiant is μ Cep.

SRd stars are giants and supergiants of F, G, or K spectral types. Amplitudes of light variation are up to 4 mag, and the range of periods is from 30 to 1100 days (e.g. SX Her).

The rest are irregular red variable stars. Their light variations are unpredictable, so non-stop photometric measurements are highly sought after. LB irregular variables are represented by giants (e.g. CO Cyg), and LC variables are supergiants (e.g. TZ Cas).

Typical examples: α Ori, Z Aqr, R Boo, T Cep, TZ Cas, RR CrB, R Leo, R Sgr, SX Her, SV Uma, AF Cyg, R Lep, R And.

ZZ Ceti (ZZ)

ZZ Ceti are a class of non-radial pulsating white dwarf stars. Falling in the instability strip of the Hertzsprung-Russell diagram, these stars pulsate with periods of minutes (mostly, up to 25 minutes). These stars are difficult to study because of their faintness and small/rapid variability. They are characterized by modest luminosity variations (from 0.001 to 0.2 V magnitudes). Sometimes, up to 1m outbursts are detected, which can be explained by the close presence of an UV Cet component.

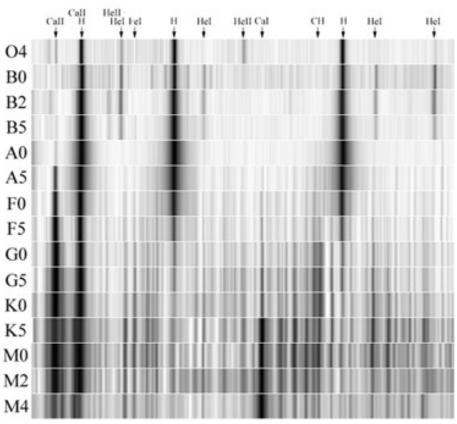
ZZ Ceti stars are divided into three subclasses:

- **ZZA** – hydrogen variables of spectral type DA, having only hydrogen absorption lines in the spectrum (ZZ Cet).
- **ZZB** – Helium variables of spectral type DB, having helium absorption lines in the spectrum (e.g. V1063 Tau).
- **ZZO** – variables of DO spectral type showing HeII and CIV absorption lines in their spectra.

On the H-R diagram, ZZ stars occupy the lower left part, and lie in a band roughly parallel to the main sequence, but several magnitudes below it.

Siarhey Hadon, Ivan Adamin

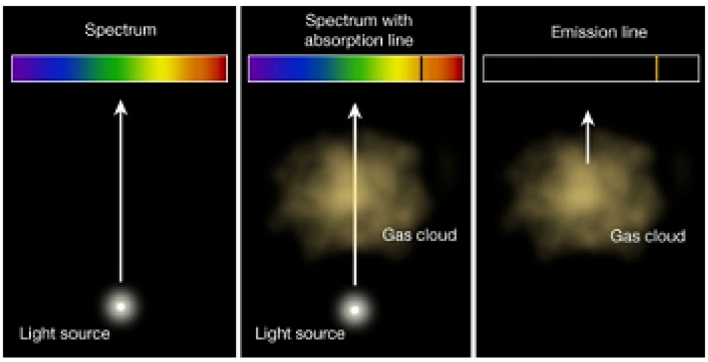
Stellar spectral classification: a brief story of early steps



Stellar spectra sequence, O to M.

While *Isaac Newton* (1643 – 1727) observed the continuous spectrum of the Sun, he missed the discovery of absorption lines. In 1802, *William Hyde Wollaston* (1766-1828) reported dark gaps between colors in the continuous spectrum. Later, *Joseph von Fraunhofer* (1787-1826) observed the Solar spectra more detailed and found that the dark gaps are different in strength. German physicist *Gustav Kirchhoff* (1824-1887) published his fundamental work in 1859, which explained the nature of the Fraunhofer lines in the solar spectrum and the composition of its atmosphere. In the 1860's, *William Huggins* (1824-1910) and his wife Margaret used spectroscopy to determine that the stars are composed of the same elements as found on Earth. Another classification scheme was proposed by Father *Angelo Secchi* (1818-1878) from Italy in 1863, who visually observed prismatic spectra of about 4000 stars and divided them into groups. By 1868, his classification defined four classes of stars. Group I was reserved for "blue-white stars showing hydrogen lines", Group II represented stars with numerous metallic lines and yellow or orange stars like Capella or the Sun; Group III was added for orange to red stars. Group IV comprised of carbon stars. In 1877, Secchi added a fifth class for emission-line stars.

In the early XX century, astronomers began photographing the spectra of stars, but the diversity of spectral features was too confusing and complex to explain. *Edward Pickering* (1846-1919) re-arranged the spectral sequence, taking into consideration the changes in other lines. Building upon this idea, a team of astronomers at the Harvard Observatory, led by *Annie Cannon* (1863-1941), grouped similar appearing spectra together, designated by letters: A, B, C, etc. They also started a project on spectra classification. Soon, a smooth sequence of spectral types was found, and the assigned letters combined into O-B-A-F-G-K-M. For better distinction, the classes were further divided into subclasses, marked from 0 to 9 within the class. The results of that work, the Henry Draper Catalog, was published between 1918 and 1924.



An example of Kirchhoff's three laws of spectroscopy. Image credit: The Pennsylvania State University

The early Harvard spectral classification system was based on the appearance of the spectra, but the physical reason for these differences in spectra were not understood until the 1930's and 1940's. Then it was realized that the main thing that determined the spectral type of a star was its surface temperature. *Cecilia Payne* (1900-1979) took the data from the HD catalog and discovered its physical significance: the great variation in stellar absorption lines was due to different amounts of ionization (differing temperatures), not different abundances of elements.

The spectral classification system used today is a refinement called the MK system, introduced in the 1940's and 1950's by Morgan and Keenan at Yerkes Observatory. A new feature was added to the classification – stellar luminosity classes (I to V), showing that stars with the same temperature can have different sizes.

Stellar associations: a variable stars nursery

The study of stellar associations and star formation regions is an important activity in the research of stars evolution and their systems. Stellar associations are concentrated along the spiral arms of our galaxy and come in several types. As a place where stars are born, these regions contain different kinds of objects, including variable stars, at the early stages of their life.

The term "stellar associations" was suggested as one of the basic concepts in the galactic astronomy by the outstanding astrophysicist of the Academy of Science of the USSR - V.A. Ambartsumian, in 1948. Stellar associations are sparse groups of loosely bound young stars, which have similar physical properties. The age of such associations does not exceed several tens of millions of years. About 90 percent of all stars originate as members of associations.

***Viktor Amazaspovich Ambartsumian** (1908 - 1996), Byurakan Observatory, Armenia. Soviet astronomer and astrophysicist, best known for his theories concerning the origin and evolution of stars and stellar systems.*

What makes associations different from regular young star clusters is their larger size and low stellar density. By size, an association can reach 50-100 pc, but the number of members can be just tens to hundreds of stars overall. Stellar associations are complex molecular clouds.

The weak gravity in associations determines their relatively short (in astronomical terms) lifetime - only 10-20 million years old. Groups' borders are continuously expanding, making it eventually impossible to distinguish an association from the background stars of “old” associations.

Stellar associations are divided into three basic types:

- *OB associations*, containing mainly massive hot blue-giant stars;
- *T associations*, containing mainly low-mass T Tauri variable stars;
- *R associations* (R stands for "reflection"), containing stars of spectral classes O to A2, surrounded by reflection nebulae, gas and dust.

OB associations consist largely of very young, massive stars (about 10 to 50 solar masses) of spectral types O to B2. These stars do not live long, so OB associations are all young. The size of OB associations ranges from 40 to 200 parsecs, and the number of members (spectral type O-B2 stars) is limited to several dozen. T associations are made up of numerous cooler lower-mass dwarf T Tauri stars, which exhibit irregular variations of brightness. R associations are characterized by medium-mass stars. A well-defined lane of R associations extends from Cygnus to Monoceros along the inner edge of the Orion arm. All three types may be found together. The internationally approved designation for associations is the name of the constellation followed by an Arabic numeral (e.g. Perseus OB2).

Left: VISTA infrared image of the star-forming region Monoceros R2 within the constellation of Monoceros (the Unicorn).

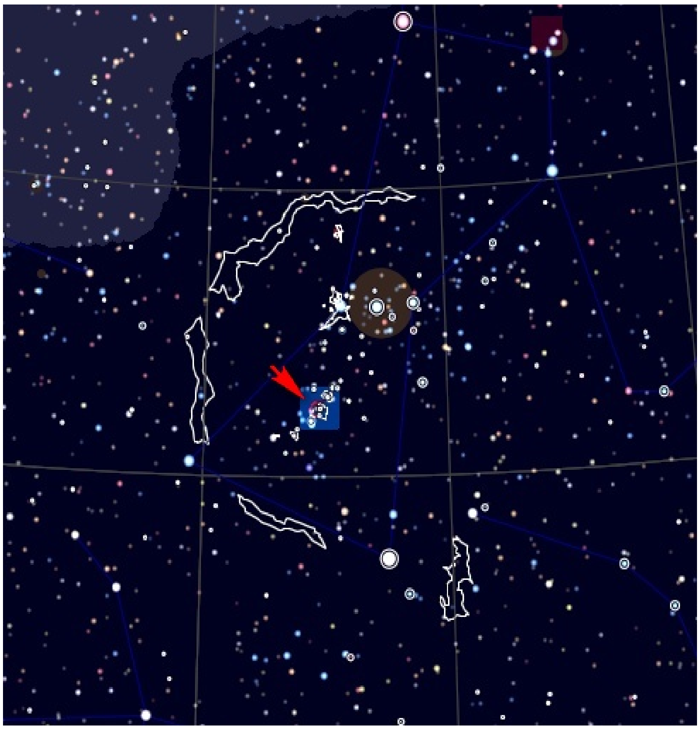
Image credit: ESO / J. Emerson / VISTA.

Nevertheless, the fact that stellar associations exist within our galaxy, along with other types of star clusters, is an irrefutable proof that the stars are not born alone, but in groups. One of the clearest examples of stellar associations, which can be seen currently in the constellation of Orion, is the "trapezium". This is a group of young blue stars. The Scorpius -Centaurus Association is the nearest OB association to the Sun. It is composed of three subgroups of stars, whose mean distances range from 380 to 470 light years.

The most interesting association type for variable stars researchers are T associations. These are home to relatively cool dwarfs with hydrogen emission lines in their spectra. Nearly 40 of such associations are currently known. These regions are formed by groups of young T Tauri variable stars associated with the clouds of interstellar matter (nebulae) in which they occur. This fact was noted by Ambartsumian and played a significant role in the future development of theoretical ideas about how stars are formed. T Tauri variables are newly formed stars of low mass (three or less solar masses) that are still in the process of contraction. Since T Tauri stars are dwarfs, T associations cannot be observed at great distances. They occur only in or near regions of galactic nebulosity, either bright or dark, and only in obscured regions showing the presence of dust.

T Tauri variable stars are in the stage of evolution before entering the main sequence, with masses less than two solar. They have spectral types of F to M; their rotation periods are on the order of 1 to 12 days. Compared to the main sequence stars, their luminosity is typically greater because of the larger size. There is evidence that their surfaces are covered with spots. Another source of T Tauri brightness variability is a protoplanetary disk surrounding the star.

The constellation of Cygnus has five T associations, and Orion and Taurus have four of them each. The richest is Ori T2, with more than 400 members; it has a diameter of 50 by 90 light-years and lies at a distance of 1,300 light-years around the variable star T Ori. This is, perhaps, the best known example of a stellar nursery, where new stars are being born, the Orion Nebula (M42) area. Observations of the nebula have revealed approximately 700 stars in various stages of formation within the nebula. Also, T associations were discovered in Monoceros, Perseus, etc.



The area containing the Orion T2 association and the M42 nebula (The Orion Nebula)

Besides T Tauri variables, another type of variable stars is found in stellar associations - UV Ceti. The most important common feature for those two classes of variable stars is a continuous emission. For UV Ceti stars the emission is observed during outbursts, while for T Tauri stars it appears at various stages of their variability cycle.

The study of variable stars in stellar associations is very important for understanding the fundamental concepts of star formation. Stars at the earliest stages of their evolution are an extremely valuable source of knowledge about the nature of their origin.

Valery Tsehmeystrenko

The list of 10 most recognizable T associations.

Association	Constellation	Nearby Object	Members Count	Angular Diameter	Approx. Distance, pc
Tau T1	Taurus	RY Tau	15	3	200
Tau T2	Taurus	T Tau	12	5	170
Aur T1	Auriga	RW Aur	15	7	170
Ori T1	Orion	CO Ori	49	4	400
Ori T2	Orion	T Ori, M42	450	4	400
Mon T1	Monoceros	S Mon, NGC2264	198	3	800
Ori T3	Orion	Σ, ζ Ori, I434	103	4	400
Sco T1	Scorpius	α Sco, ρ Oph	33	9	210
Del T1	Delphinus	V536 Aql, WW Vul	25	15	200
Per T2	Perseus	I348, ζ Per	16	0.4	380

Discovery of a Second Radial Mode in the High Amplitude Delta Scuti Star NSVS 10590484 (GSC 01489-00914)

Klaus Bernhard (1,2), **Stefan Hümmerich** (1,2)

1 - Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne e.V. (BAV)
2 - American Association of Variable Star Observers (AAVSO)

Abstract: During an investigation of the pulsational behaviour of Delta Scuti stars, we have identified a second radial mode in the High Amplitude Delta Scuti star NSVS 10590484 (GSC 01489-00914) which was discovered by Alexandr Ditkovsky of the VS-COMPAS team. Therefore, NSVS 10590484 is an HADS(B) star with the following elements:
P0= 0.0541911 d; P1= 0.0419105 d (P1/P0= 0.7734).

I. Introduction

Delta Scuti (DSCT) stars are pulsating variables with short periods (about 0.01 to 0.2 days) and light amplitudes ranging from a few thousandths to a few tenths of a magnitude in the visual band of the spectrum. They are located in the lower part of the Cepheid instability strip and are thus situated on or just off the densely populated main sequence. Consequently, they are among the most numerous pulsating variables among the brighter stars (cf. e.g. Percy, 2007).

DSCT stars are of intermediate mass and mostly occur between spectral types A5 to F2, usually falling into luminosity classes IV or V (e.g. Moya et al., 2010). While their typical range is on the order of a few hundredths of a magnitude, there are also DSCT stars with amplitudes of up to 0.9 mag (V). Generally, objects with an amplitude greater than 0.2 mag (V) are called High Amplitude Delta Scuti (HADS) stars. They are characterized by non-sinusoidal light curves, small rotational velocities and are rare objects; according to Percy (2007), less than one per cent of DSCT stars have amplitudes exceeding 0.3 mag (V). Another subgroup is constituted by the SX Phoenicis stars – metal-poor DSCT stars with large amplitudes that are very old objects in an advanced state of evolution and belong to Population II.

Many DSCT stars are multi-periodic and exhibit complex pulsational patterns. Because of this – and the small amplitudes of the pulsation modes – great care has to be taken in period analyses. Moreover, DSCT stars are notorious for exhibiting non-radial pulsations. In the DSCT star FG Virginis, for example, the astonishing number of 79 frequencies were detected by Breger et al. (2005), who analyzed nearly continuous photometry obtained from a multi-longitude campaign. The large-amplitude HADS stars, on the other hand, pulsate mainly in radial modes, although there is growing evidence that non-radial modes with small amplitudes may also be excited in these objects (e.g. Pigulski et al., 2006).

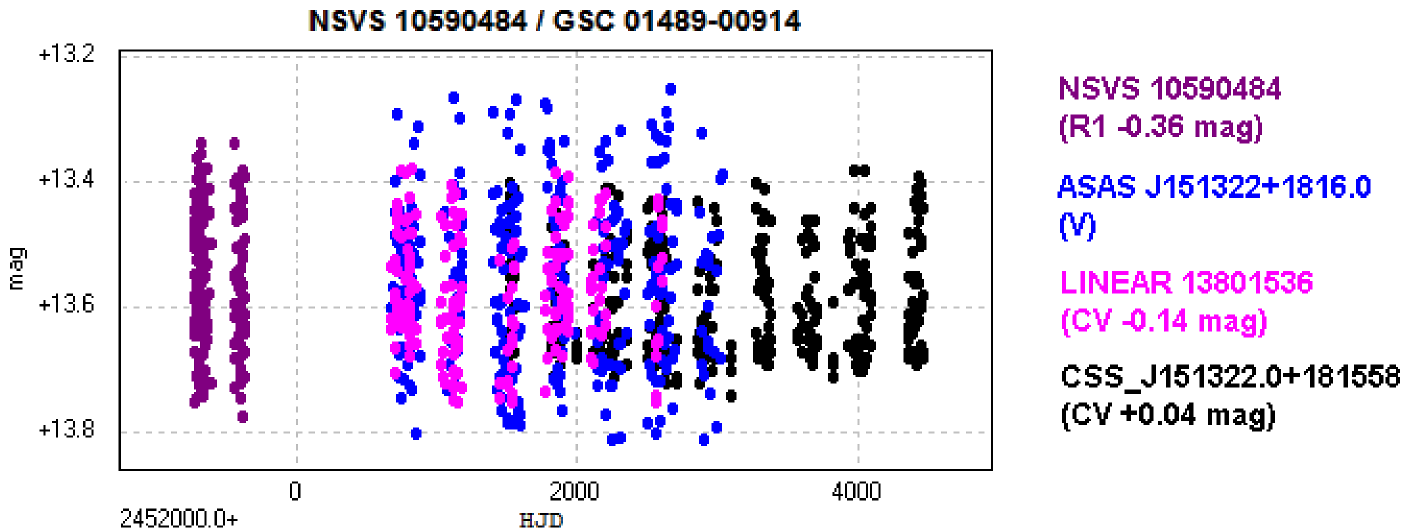


Figure 1. – Light curve of NSVS 10590484 (GSC 01489-00914), based on data from various sky surveys as indicated in the legend on the right side. In order to facilitate period analyses, NSVS, LINEAR and CSS data have been shifted by the indicated amounts to match ASAS-3 V data.

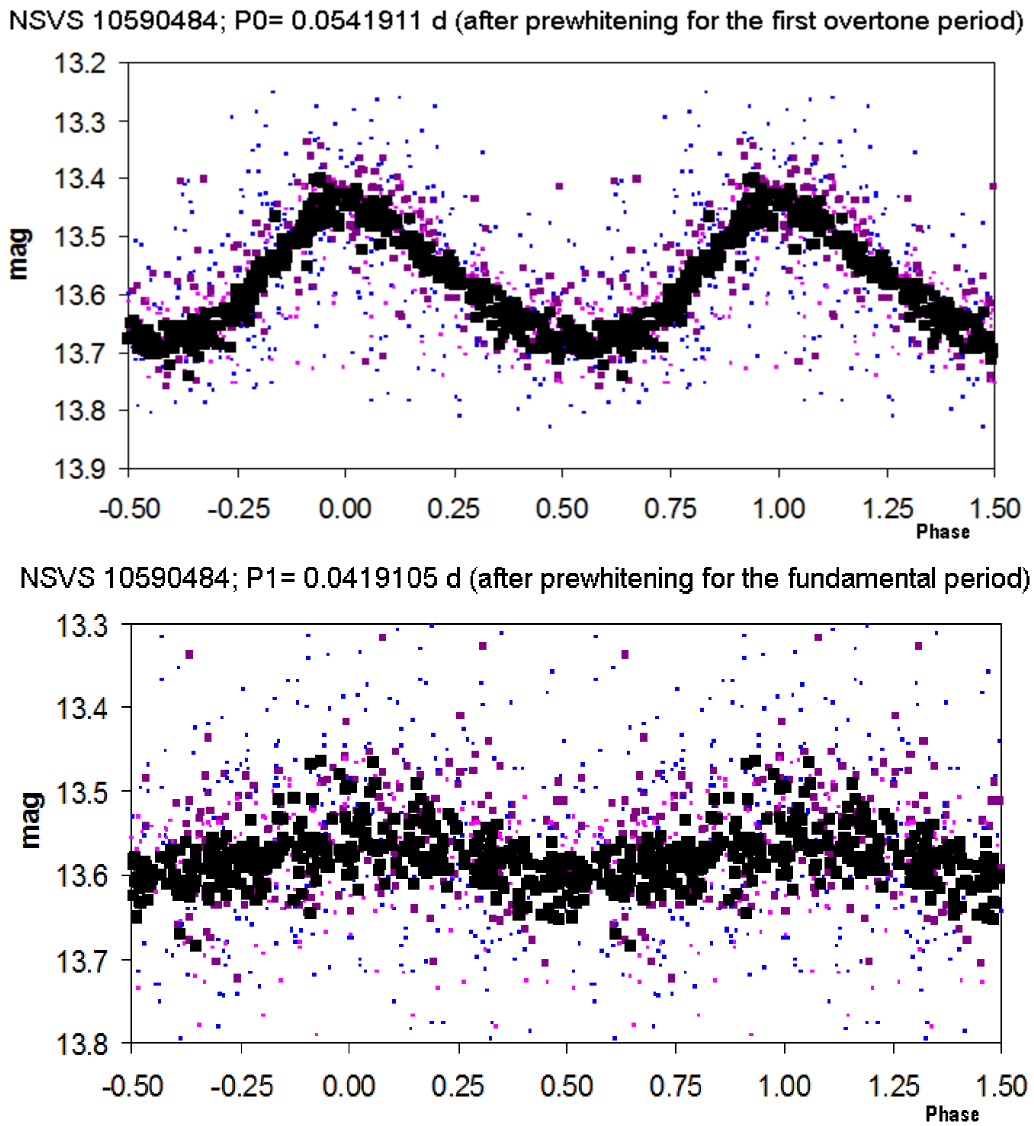


Figure 2. – *Phase plots of NSVS 10590484 (GSC 01489-00914), illustrating the fundamental and first overtone modes. Data and colours are the same as in Figure 1.*

II. NSVS 10590484 (GSC 01489-00914)

NSVS 10590484 (GSC 01489-00914), located in the constellation Serpens (RA, Dec (J2000)= 15:13:22.007 +18:15:58.31; UCAC4), was identified as an HADS variable by Alexandr Ditkovsky from the VS-COMPAS team in 2012 (http://www.aavso.org/vsx/index.php?view=detail.top&oid=283102). The star was submitted to the AAVSO International Variable Star Index (VSX; Watson et al., 2006) with the elements

HJD(Max)= 2455981.032 + 0.0541911 * E. (1)

During an investigation of the pulsational behaviour of HADS stars, we have analyzed available data from the NSVS (Woźniak et al., 2004), ASAS-3 (Pojmański, 2002), LINEAR (Stokes et al., 2000) and CSS (Drake et al., 2009) databases for NSVS 10590484 using Period04 (Lenz and Breger, 2005). In addition to confirming the period determined by Ditkovsky, we were able to identify an additional peak in the power spectrum of NSVS 10590484 at a frequency of 23.860351 cycles per day which corresponds to a period of P= 0.0419105 days (cf. Figure 3). While this signal is of low amplitude, the derived signal-to-noise ratio of 6.3 – calculated using Period04 – indicates a significant detection. Furthermore, the period ratio of P1 / P0= 0.7734 is indicative of radial pulsation and unmasks the additional period as the first overtone mode. We are thus confident of the reality of the detected additional frequency.

The light curve of NSVS 10590484 is given in Figure 1. Phase plots illustrating the fundamental and first overtone periods are shown in Figure 2. A Petersen diagram – a diagram plotting the period ratios versus the fundamental mode periods – is often used to study double-mode radial pulsating stars (cf. e.g. Poretti et al., 2005). We present a Petersen diagram of a sample of well known Galactic double-mode HADS stars and NSVS 10590484 in Figure 4. The location of NSVS 10590484 in this diagram is consistent with that of other Galactic HADS(B) stars.

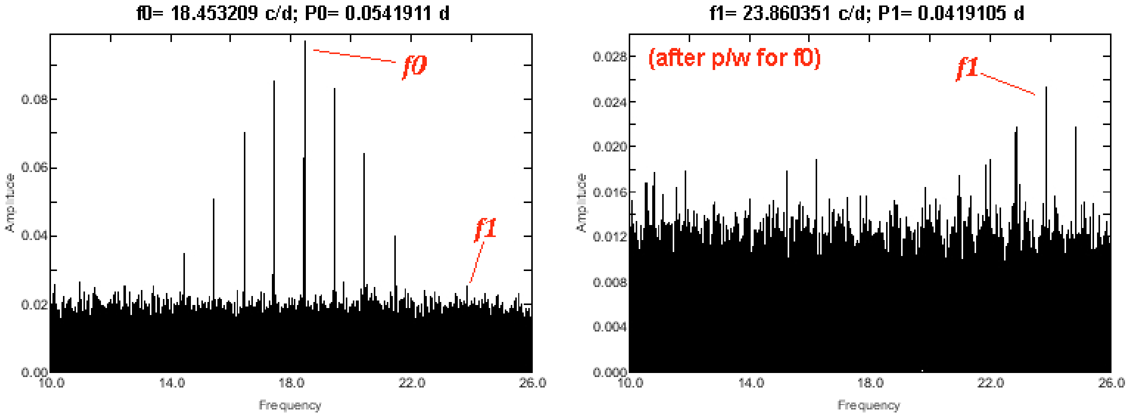


Figure 3. – *Power spectra of NSVS 10590484 (GSC 01489-00914) for the combined dataset as specified in Figure 1 (left side) and after substraction of the fundmental mode frequency (right side).*

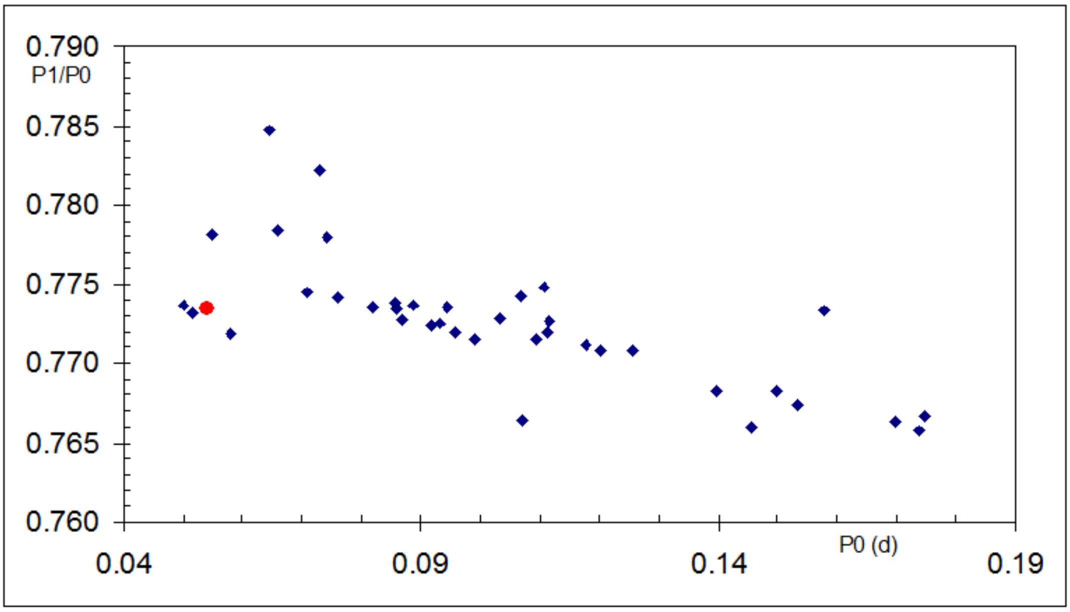


Figure 4. – *Petersen diagram for a sample of well-known Galactic double-mode HADS stars with period ratios in the range between 0.76 and 0.79 (blue diamonds; N= 38) and NSVS 10590484 (red circle). Data were taken from the VSX.*

We encourage further photometric and spectroscopic studies with high time resolution.

III. References

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- Drake, A. J. et al., 2009, Astrophysical Journal, 696, 870
- Lenz, P.; Breger, M., 2005, Comm. in Asteroseismology, 146, 53
- Moya, A. et al., 2010, ArXiv e-prints, arXiv:1004.0100
- Percy, J. R., 2007, "Understanding variable stars", Cambridge University Press
- Pigulski, A. et al., 2006, Memorie della Società Astronomica Italiana, 77, 223
- Pojmański, G., 2002, Acta Astronomica, 52, 397
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- Project VS-COMPAS, 2011-2014, http://vs-compas.belastro.net/
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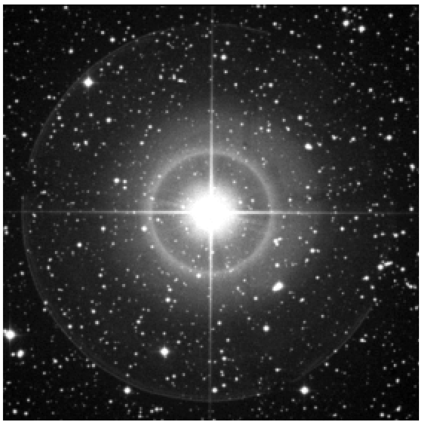
Acknowledgements: This publication has made use of the SIMBAD and VizieR databases operated at the Centre de Données Astronomiques (Strasbourg) in France, of the International Variable Star Index (AAVSO), and of the Two Micron All Sky Survey (2MASS). The authors thank Sebastián Otero for providing VSX data on Galactic HADS(B) variables.

Notable long-period eclipsing binaries. Part I.

Long-period eclipsing binary stars are very important for stellar astrophysicists, because they offer the chance to study the characteristics of isolated stars with a high degree of precision and accuracy. The most interesting fact about eclipsing binaries is that all kinds of stars are found as members of binaries: from normal main sequence stars, variable stars, evolved giants and supergiants, to collapsed objects. Here a list of several interesting long-periodic systems is presented.

Detached eclipsing binaries can provide fundamental physical properties of the components through the analysis of light and radial velocity curves. This allows to determine masses, radii and luminosities of individual stars and provides test bases for stellar structure and evolution models, and internal structure of stars.



The issue with long-period systems is that eclipse events are quite rare to happen, so their photometric coverage is very valuable, providing a good chance to scientists to gain more statistical data. Not all wide-field photometric surveys have details on even a single eclipse event per long-period eclipsing variables, as they are conducted for a limited period of time.

Below is a set of interesting targets for amateurs that are in need of observations. Each star is accompanied by an image of the star's 12.9 arcmin neighborhood, provided by the *Aladin Sky Atlas* - http://aladin.u-strasbg.fr. Detailed star charts along with photometry tables can be obtained via AAVSO's *Variable Star Plotter* (VSP), available at http://www.aavso.org/vsp

Epsilon Aurigae, Zeta Aurigae and VV Cephei (the next eclipse is expected in 2017) were described in details in separate articles in the bulletin. For **Zeta Aurigae** (see the top-right image here), the next eclipse is expected in July 2014; totality usually lasts for 37 days. So you have enough time to get prepared!

AZ Cassiopeiae

Cassiopeia; J2000: RA = 01h 42m 16.5s; DEC = +61d 25m 16.4s;
Mag.: 9.22 - 9.52 V; Period: 3402 d (9.3 yr); Next eclipse: April 2022

Unfortunately, the most recent eclipse was in January 2013, so the next one is really far away. The variability of AZ Cas was discovered by Beljawski (1931), while the period was determined 25 years later, by Ashbrook in 1956 (see Tempesti, 1979; AASS, 39, 115). In 1947 C. Hoffmeister classified the variable as an R CrB-like star, but Ashbrook found the star to be an eclipsing binary (Larsson-Leander, 1960; Arkiv för Astronomi, 2, 347);

The AZ Cas system consists of an M0I supergiant and B0V hot component (Cowley, Hutchings, & Popper 1977). Its orbital period is 9.3 years with an eclipse duration of ~100 days. No significant light variations in UBVRI outside the eclipse have been found (Nha 1994; Lee & Gim 1994). The spectroscopic orbital parameters revealed an eccentric orbit, e=0.55 (Mikolajewski et al., 2004; ASPCS, 318)

AZ Cas Campaign 2012 – 2014 online:
http://www.astri.uni.torun.pl/~cgalan/AZCas
http://www.astrosurf.com/aras/surveys/azcas/index.htm

EE Cephei

Cepheus; J2000: RA = 22h 09m 22.8s; DEC = +55d 45m 24.2s;
Mag.: 10.72 - 12.15 V; Period: 2050 d (5.6 yr); Next eclipse: August 2014

The eclipsing nature of EE Cep, with a period of 5.6 years, was established after three successive events: in 1958, 1964 and 1969 by Meinunger (1973). The most striking features of the EE Cep minima are large changes of their shape (Graczyk et al. 2003). The observed depths of minima range from about 2m to about 0.m6. Also, the total duration of particular eclipses changes from about 3 weeks to about 2 months. (see Mikolajewski et al., 2004; ASPCS, 318).

V695 Cygni (31 Cyg, o[1] Cyg)

Cygnus; J2000: RA = 20h 13m 37.9s; DEC = +46d 44m 28.8s;
Mag.: 3.73 - 3.89 V; Period: 3784.3 d (10.36 yr); Next eclipse: March 2024

Another remarkable star with an extremely long period between eclipses. Sadly for those observers who look forward to capture the event soon, its eclipse has just ended. Another is expected in ten years – in 2024. Eclipse duration is two months long. The secondary eclipse occurs at phase 0.64, or 2422 days. A good comparison star is *30 Cyg*, while *26 Cyg* can be used as the check star. The system 31 Cygni is a member of a relatively rare group of eclipsing stars, each composed of a late-type supergiant and a component of early spectral type. It was discovered as a spectroscopic binary in 1901 (Campbell 1901); provisional elements were determined by Christie in 1936 (see Bloomer & Wood, 1973; PASP, 85, 348). For 1982 eclipse analysis please refer to the following publications:

- Stencel, R. E., Hopkins, J. L. et al., 1984; "The 1982 eclipse of 31 Cygni", ApJ, 281, 751
- Hagen Bauer, W., 1994; "Spectroscopic observations of the 1982 eclipse of 31 Cygni", PASP, 106, 244

V1488 Cygni (32 Cyg, o[2] Cyg)

Cygnus; J2000: RA = 20h 15m 28.3s; DEC = +47d 42m 51.1s;
Mag.: 3.90 - 4.14 V; Period: 1147.6 d (3.15 yr); Next eclipse: October 2015

This star system is similar to the 31 Cygni system and is also a member of the group of Zeta Aurigae systems. 32 Cygni is a 4th magnitude star and has a period of 3.15 years. Eclipse totality lasts for 11 days, while ingress/egress is 8.5 days long each. Secondary eclipse occurs at phase 0.65, or 746 days from the primary. Same as for 31 Cygni, *30 Cyg can be used as the* comparison star, and *26 Cyg* - as the check star.

During an eclipse, emission lines can be seen in the spectrum of this system. These originate in the stellar wind escaping from the giant star. In a volume around the B star, this wind becomes ionized, resulting in a circumstellar H II region (Eaton, 2008; JAD, 14, 3). For detailed analysis of variability, refer to:

- Fox, G. K. & Griscom, L., 1996; "The polarimetric variability of 32 Cyg during its 1993 October eclipse", MNRAS, 278, 975
- Dolzan, A., 1987; "32 Cyg: UBV Photometry of Eclipse in 1987", IBVS, 3112
- Gehlich, U. K., Prölss, J., & Wehmeyer, R., 1972; "Photoelectric observations of the 1971-eclipse of 32 Cyg", Astr. and Astroph., 20, 165

22 Vul / QS Vul

Cygnus; J2000: RA = 20h 15m 30.2s; DEC = +23d 30m 32.0s;
Mag.: 5.03 - 5.27 V; Period: 249.1 d; Next eclipse: August 2014

This star system is a new member of the Zeta Aurigae group. This 5th magnitude star system was discovered during the 1984 eclipse. The eclipse in the "V" band is only 0.05 magnitudes but increases to nearly 0.2 magnitudes for the "B" band and nearly 0.5 magnitudes in the "U" band. Ingress and egress are usually 1 day long, while the totality lasts for 8-10 days.

This system is unique as it is the first one found with a G-type primary, while the spectral type of the secondary is the latest (B9) of all Zeta Aurigae binaries. The period is also short for systems of that kind. More detailed analysis of photometric and spectroscopic measurements during the 1984 eclipse is available in the following publications:

- Ake, T. B. et al., 1985; "The newly discovered eclipsing supergiant 22 Vulpeculae", ApJ, 298, 772
- Parsons, S. B., et al., 1985; "The August 1984 eclipse of 22 Vulpeculae", PASP, 97, 725

tau Persei (18 Per)

Perseus; J2000: RA = 02h 54m 15.5s; DEC = +52d 45m 44.9s;
Mag.: 3.93 - 4.09 V; Period: 1515.81 d; Next eclipse: February 2018

Tau Persei was found by Ake et al. (1986) to be an eclipsing binary. This G5 III + A2 V system has a highly eccentric orbit (e = 0.74) and is oriented in such a way, that superior conjunction of the secondary occurs near periastron. The astrometric orbit by McAlister (1981) from speckle observations indicates high inclination: i = 95 ± 2.4 degrees. The UV spectra during eclipse are found to have added line absorption due to the atmosphere of the G star superimposed on the A-type spectrum (Ake et al., 1986). The high inclination of the orbit leads to the question of eclipses. Based on observed data of 1984 and 1989 events, the eclipse is 84% total (Hall et al. 1991). Typical eclipse lasts for 2-3 days.

- Hall, D. S. et al., 1991; "Worldwide photometry of the January 1989 Tau Persei eclipse", AJ, 101, 1821
- Demircan, O., Selam, S. O., 1992; "A long-period eclipsing binary Tau Persei", Astr. & Astroph., 259, 577
- Ake, T. B. et al., 1985; "Discovery of an Atmospheric Eclipse of tau Per", IBVS, 2847, 1

gamma Persei (23 Per)

Perseus; J2000: RA = 03h 04m 47.8s; DEC = +53d 30m 23.2s;
Mag.: 2.91 - 3.21 V; Period: 5346 d; Next eclipse: December 2019

Gamma Persei is a spectroscopic binary with a period of 14.6 years. It is even an eclipsing binary, where a small magnitude drop can be observed at the time of eclipse. The eclipse was first observed in September 1990 and lasted for two weeks (Griffin et al., 1994). The duplicity of Gamma Persei was first recognized by Miss Maury in 1897, based on the analysis of its spectrum.

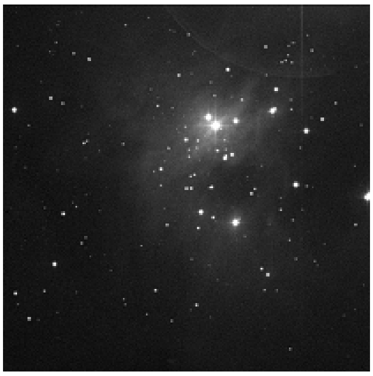
- Griffin, R. F. et al., 1994; "The Eclipse of Gamma Persei", International Amateur-Professional Photoelectric Photometry Communication, 57, 31
- Pourbaix, D., 1999; "Gamma Persei: a challenge for stellar evolution models", Astr. & Astroph., 348, 127
- Popper, D. M.; McAlister, H. A., 1987; "Gamma Persei - Not overmassive but overluminous ", AJ, 94, 700

V0481 Persei (BD+49 1130) – *the chart is on the right*

Perseus; J2000: RA = 04h 13m 08.8s; DEC = +49d 42m 35.3s;
Mag.: 12.0 - 13.2 p; Period: 1496 d; Next eclipse: February 2015

V0718 Per (Herbig 187, IC 348)

Perseus; J2000: RA = 03h 44m 39.2s; DEC = +32d 07m 35.6s;
Mag.: 12.95 - 13.65 Ic; Period: 1716 d; Next eclipse: Feb-Mar 2015



Extremely interesting object. The remarkable pre-main-sequence object V718 Per (HMW 15, H187) in the young cluster IC 348 periodically undergoes long-lasting eclipses. The light curve is flat-bottomed and rather symmetric, with a depth of 0.66 mag. During eclipse, the system reddened by ~0.17 mag in R-I (Cohen et al., 2003), confirmed by Nordhagen et al. (2006). The duration of each eclipse is at least 3.5 yr, or ~75% of a cycle, verifying that this is not an eclipse by a stellar companion. It may be an eccentric binary in which a portion of the orbit of one member is currently occulted during some binary phases by a circumbinary disk. The star deserves sustained observational attention for what it may reveal about the circumstellar environment of low-mass stars of planet-forming age. (Nordhagen et al., 2006). Late 2004, V718 Per entered a second eclipse, in shape and depth very similar to the first one. (Barsunova et al. 2005). More detailed observations by Nordhagen et al. (2006) show that V718 Per undergoes recurrent, 3.5 year long eclipses with a period of P = 4.7 ± 0.1 years (see also Grinin et al. 2006a). Thus, given the very long eclipse duration and its comparitively short period, this system is one of the most exotic eclipsing systems known.

- Grinin, V. et al., 2008; "The unusual pre-main-sequence star V718 Persei...". Astr. & Astroph., 489, 1233
- Grinin, V. et al., 2006; "On the nature of the unique eclipsing system H 187 (HMW 15)", Astr. Lett., 32, 827
- Nordhagen, S. et al., 2006; "The Recurrent Eclipse of an Unusual [..] Star in IC 348", ApJ, 646, 151
- Cohen, R. E. et al., 2003; "An Unusual Eclipse of a Pre-Main-Sequence Star in IC 348", ApJ, 596, 243

RZ Oph (HIP 92055)

Ophiuchus; J2000: RA = 18h 45m 46.4s; DEC = +07d 13m 12.3s;
Mag.: 9.65: - 10.42 V; Period: 261.9277 d; Next eclipse: August 2014

The long period Algol-type binary RZ Oph is known for more than a century. It was also observed in summer 1981 at the University Observatory in Brno. Analysis of the circumstellar Balmer emission lines indicates that the primary is surrounded by an extensive, highly flattened disk of nonuniform density (Baldwin, 1978).

- Baldwin, B. W., 1978; ApJ, 226, 937
- Olson, E. C., 1993; AJ, 106, 754
- Forbes, D. & Scarfe, C. D., 1984; PASP, 96, 737
- http://www.as.up.krakow.pl/o-c/data/getdata.php3?RZ%20OPH

OW Gem (SAO 95781)

Gemini; J2000: RA = 06h 31m 41.8s; DEC = +17d 04m 56.3s;
Mag.: 8.22 - 9.6 V; Period: 1258.59 d; Next eclipse: October 2015

This eclipsing binary consists of two supergiants: an F2 Ib-II primary and a a cooler, fainter giant companion G8 IIb secondary. Variability of the system was discovered by Kaiser in 1988. The AAVSO's eclipsing binary team has conducted a multi-filtered international campaign on OW Gem covering the primary and secondary eclipses in 1995 and 2002.

- Terrell et al., 2003; "The Double Supergiant Binary OW Gem", AJ 126, 902
- Kaiser, D.H. : 2002 (IBVS 5347), 1988 (IBVS 3233), 1988 (IBVS 3196)

NSV 10028 (USNO-B1.0 0943-0320829)

Ophiuchus; J2000: RA = 18h 01m 55.4s; DEC = +04d 22m 16.4s;
Mag.: 11.55 - 12.43 V; Period: 704 d; Next eclipse: June 2014

NSV 10028 is an orange star that seems to undergo 0.8-0.9 mag fadings. This may be a long period eclipsing binary, according to Hoffmeister's 1967 discovery and interpretation, but may be an RCB object as well. It takes more than 40 days for the star to recover. Very interesting object to follow, due to an almost 0.9 mag range. The question if the object is periodic is still open.

http://www.astrouw.edu.pl/cgi-asas/asas_lc/180156+0422.3

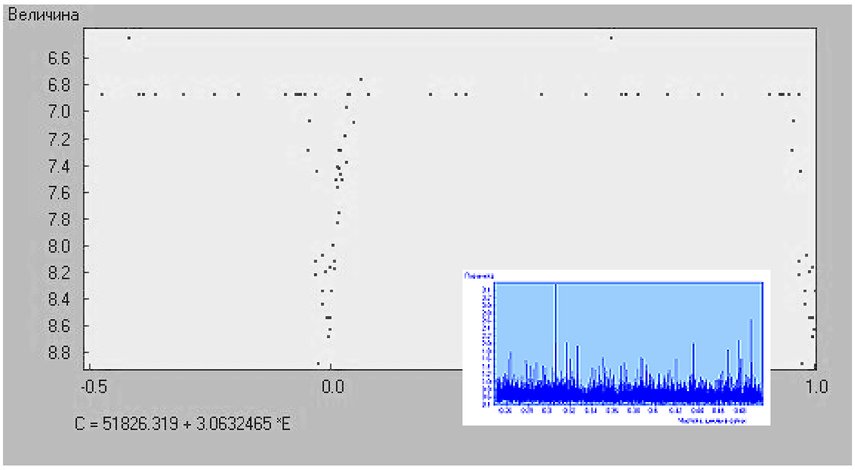
Remarkable objects from the South celestial hemisphere will be described in the second part. Generally, observations should be started at least a month prior to the predicted eclipse date, in order not to miss an event.

Acknowledgements: This publication has made use of the SIMBAD, VizieR databases, and Aladin Sky Atlas operated at the Centre de Données Astronomiques (Strasbourg) in France, of the International Variable Star Index (AAVSO).

Eclipsing variable TX UMa: my observations

TX UMa is an eclipsing binary system. This article presents a summary of my visual observations, made from the city of Pavlodar, Kazakhstan. The measurements were made time-to-time throughout several years, so the task was mostly an interesting challenge and eye training at the same time. The result has a good match with the known period.

The eclipsing binary TX Ursae Majoris is located 13 degrees south-west from the famous Big Dipper, between Lambda and Psi UMa, and one degree from a 5m star in its vicinity. This allows the star to be found visually quite easily. Precise coordinates are the following:



TX Uma (J2000.0)

RA = 10h 45m 20.5s

DEC = +45d 33m 58.8s

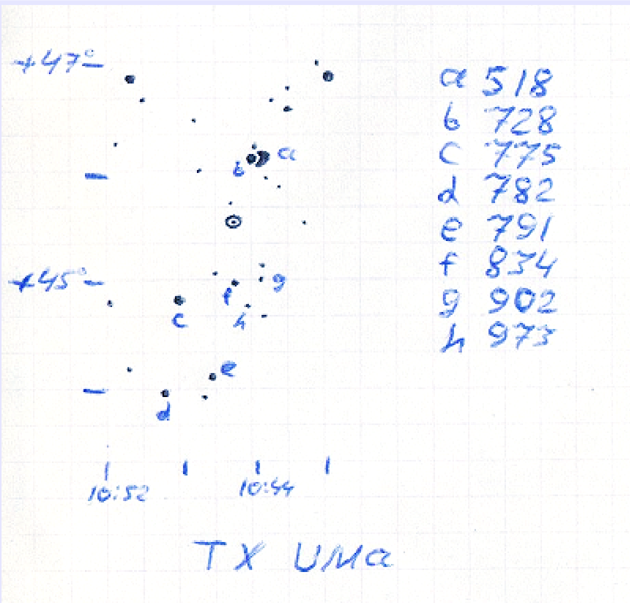
A location chart along with the comparison stars is given below. As TX Uma is an eclipsing detached binary, it spends most of its time in "out-of-the-eclipse" state, having an average brightness of 6.9m. Every 3 days 1 hour and 32 minutes its brightness dims to 8.8m. The star is a good target to look at with binoculars. A light curve built from my observations can be seen just above. The eclipse lasts for 8 hours 50 minutes, so every 15-18 minutes the star adds 0.1m to its brightness.

Based on my observations, the minimum of TX UMa can be calculated using the following equation:

$$T = 2451912.095 + 3.0632465 \times E.$$

Due to the fact that the period of TX UMa is close to 3 days, every 45 days there is a sequence of 3-4 nights with the eclipse phase visible every night. This is very convenient for observers.

The main purpose of this note is to encourage amateur astronomers to observe the eclipsing variable star TX Uma, and other variables, and create a more dense series of observations. This will allow to find a more reliable period value.



Historical reference

In 1925, the star HD 93033 was discovered as a spectroscopic binary. Rugemer, in 1931, proved its eclipsing nature and later found that its period was not constant (Kreiner & Tremko, 1980). A detailed analysis of the photometric material was carried out by Plavec (1960) who substantiated the conclusions concerning the existence of the apsides line rotation. This caused the shape of the light curve of the primary minimum to change.

More detailed analysis of possible motion of the line of apsides in the system of TX UMa is published in (Kreiner & Tremko, 1980; BAICz, 31, 343).

Andrey Semenyuta

Authors wanted!

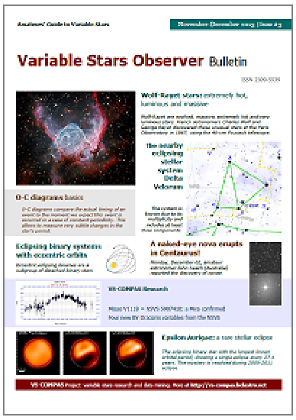
We invite authors and amateur researchers to publish their articles in the Variable Stars Observer Bulletin. If variable stars is your passion and you have something interesting to say to the community – go ahead and contribute! No matter whether your article is a strict scientific text reporting your 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 in a good reading 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.

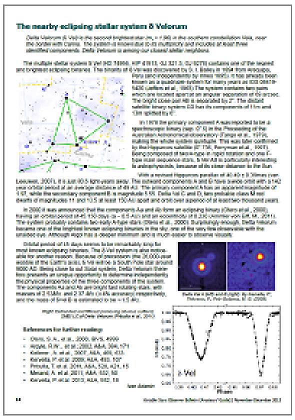
Pure scientific texts often require a solid background in math and astrophysics, but what we can do is to create a simplified overview of those papers. This intention follows a very clear goal: to provide a simple join-point for amateurs to advanced scientific research, taking into account their basic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

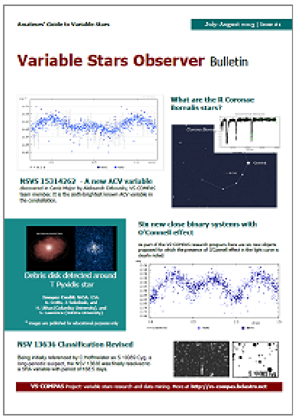
Authors making research in the field of variable stars are welcome to publish their articles in the following issues! Should you have an article ready for sharing with the community, just contact us, so we can schedule it.

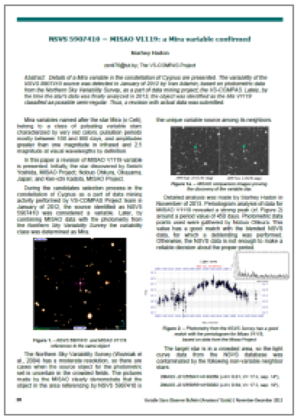
So far, we have prepared four issues, so everyone can check out the overall concept behind the project. Do not hesitate to forward your questions to vs-compas@belastro.net.

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