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New discoveries of variable stars and implications for variability-type statistics

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We review the changes of our understanding of classification and statistics of variable stars following from mass discoveries of variable stars in ground-based and space-borne surveys. By now, we know only a small fraction even of those stars that show moderate-amplitude (by at least $0^m.02$) photometric variations and almost nothing about microvariability, at the scale of $0^m.0001-0^m.001$. Thus, our understanding of the variable-star classification is based on insufficient material, and if the classification system is revised right now, a new revision will be badly needed within years. The statistics of the existing variability types is biased in a manner not easy even to explain, and many new types emerge all the time. The future prospects of variable-star catalogs remain unclear and need attentive consideration.

Keywords: Stars: variable; Stars: catalogs

1 Introduction

The General Catalogue of Variable Stars (GCVS) is a project initiated in Russia on behalf of the International Astronomical Union (IAU) in 1940s (Kukarkin and Parenago, 1948). The first GCVS contained about 10000 stars. Five major GCVS editions have been published since, with numerous supplements. These catalogs are intended to include reliable variable stars, studied sufficiently well to permit at least a preliminary classification in the existing system of variability types. For stars not satisfying these criteria, three catalogs of "suspected variable stars" were also published in the frame of the GCVS project. The history of the GCVS was reviewed in detail by Samus (2009). Currently, the GCVS project is regularly supported as an electronic catalog (Samus et al., 2011). As of mid-2011, the number of our Galaxy's GCVS stars was about 43500 (Kazarovets et al., 2011), with additional ∼15000 cataloged as variability suspects. The GCVS is being compiled as an authorized catalog, with its entries

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checked and evaluated by the author team. Meanwhile, the flow of new discoveries is so large that the GCVS compilers, regularly preparing the so-called Name-Lists (lists of stars officially accepted to the GCVS; the most recent one, No. 80, is expected to contain a total of about 6000 stars) of ever increasing volume, are considerably behind the flow. Thus, the International Variable Star Index (VSX), supported by the American Association of Variable Star Observers, where new discoveries are added immediately, even before a detailed evaluation of the discovery announcements, currently (October, 2011) contains about 200000 variables.

Obviously, traditional practice of star-by-star data evaluation for variable-star catalogs should be replaced with a new, computer-based system. However, this is a difficult task because of lack of standardization of data presentation, of effective software for automatic classification, and because of other problems. In many cases, classification solely from the light curve is impossible; additional information on spectroscopic characteristics, X-rays, radial velocity variations is needed. A brief discussion of the existing problems can be found in Samus (2009). These problems also include the necessity to revise the existing classification scheme. In 2006, IAU Commission 27 "Variable Stars" established a working group with the task to evaluate the situation and suggest solutions for future variable-star catalogs (see http://www.sai.msu.su/gcvs/future/future.html). So far, the group has not been able to suggest a realistic way out.

This paper reviews some new aspects of variable-star classification that follow from new discoveries of variable stars. When possible, we base our considerations on our own research or on publications by other authors in our electronic journal "Peremennye Zvezdy/Variable Stars".

2 General variability statistics

The USNO-B1.0 catalog (Monet et al., 2003) contains 1,042,618,261 objects (stars and galaxies), about 1 billion of them are stars to magnitudes as faint as 20^m-21^m. Experience of CCD observations accumulated by us and by other groups shows one star of 80–100 to be detectable as a variable for photometric uncertainties of $0^m.03-0^m.05$. This means that about 10 million variable stars are potentially detectable with a ground-based 1-m telescope, ordinary CCD detector, and standard software for automatic search for variable stars.

Meanwhile (Section 1), the most complete lists of already known variable stars contain about 200000 variables. Thus, we know only about 2% of all stars variable at the level detectable with very modest equipment.

The situation is actually twice worse compared to the known problem of barion matter, dark matter, and dark energy, where we believe to know some 4% of all matter. Though variable stars are considered traditional, very well studied field of astronomy, we attempt to judge about properties of this class of stars from its tiny fraction, possibly reflecting the statistics wrongly, even for comparatively large-amplitude stars.

Recent space missions, CoRoT and Kepler, provide unprecedented photometric accuracy.

Snellen et al. (2009) studied CoRoT observations of the star HD 189733 with the transiting exoplanet CoRoT-1b. Along with the photometric effect of the transit,

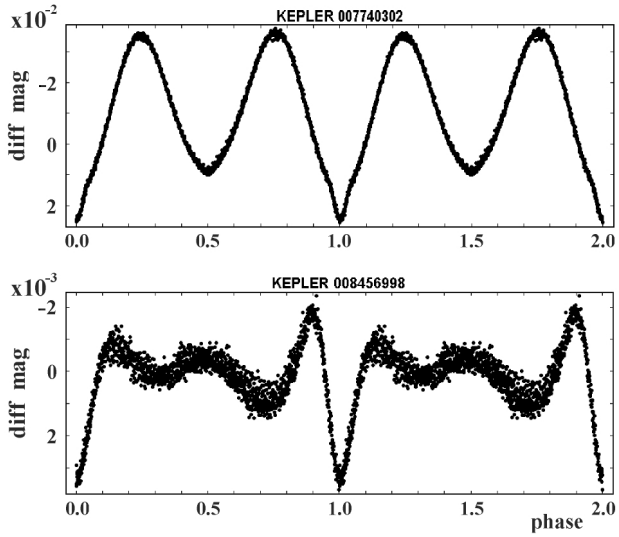


Figure 1 The light curves of two small-amplitude eclipsing variables based on Kepler photometry (after Greaves, 2010).

amounting to $0^m.02$, they revealed a reflection effect on the planet surface and the eclipse of the planet by the star disk. Both effects are of the order of 10^{-4}, or $0^m.0001$. CoRoT observations of planetary transits also reveal photometric effects of star spots (or star-spot groups) covered by the planet's disk (cf. Valio, 2011).

Greaves (2010) published a discovery announcement for three variables from the Kepler database. The smallest-amplitude one has a peak-to-peak amplitude of only $0^m.006$ (Fig. 1); nevertheless, not only the star's variability and period are beyond doubt but the light curve permits us to recognize minor details. It should be recalled that the Kepler mission is able to detect a transit of an earth-type planet across a solar-type star at a 4σ level.

The Kepler mission is monitoring about 150000 stars in a field in Cygnus and Lyra. According to Basri et al. (2011), about 60000 of them vary periodically and some 34000 stars, with poorly detectable periodicity or aperiodically. Detected variables have amplitudes from about $0^m.0001$ and even less. This means that Kepler mission will announce approximately 100000 new variable stars in *one sky region*. With this Kepler statistics, we can expect some 600 000 000 variable stars among one billion USNO-B1.0 stars. Obviously, we know close to nothing about the real statistics of variable stars, of variability types for amplitudes that small. Maybe it is too early for the IAU Commission 27 to revise the GCVS classification?

3 News on classification and statistics from ground-based data

New techniques of ground-based observations and data reduction also change our ideas on variability types and on statistics of variable-star types. CCD surveys with small telescopes, like ASAS (Pojmanski, 2002), NSVS (Woźniak et al., 2004), or

various subsequent projects provided many thousands of new discoveries and still make it possible for researchers, professional astronomers and amateurs, to continue discovering new variables. Digitization of astronomical photograph collections makes it possible to apply effective algorithms, developed for detecting variable stars in electronic images, to plate stacks accumulated at different observatories.

Among pulsating stars, unexpected phenomena were found. One of them is RR Lyrae variables with two excited frequencies differing very little. For example, Antipin and Jurcsik (2005) found, for the RRC variable ASAS 081933–2358.2, two simultaneously excited periods: $0^d.285665$ and $0^d.296111$, both with peak-to-peak variation amplitudes about $0^m.2$. A popular explanation of the phenomenon is a non-radial mode pulsation excited in the vicinity of the radial-mode frequency.

The number of known double-mode Cepheids is quickly increasing. In 2000, we knew only 18 such stars, and already 38 of them were known by 2010. Among these 38 stars, 23 reveal pulsations in the fundamental mode and in the first-overtone mode, and 15 stars pulsate in the first-overtone and second-overtone modes (while only one variable of the latter kind was known till recently). Figure 2 (Khruslov, 2010) shows the light curves of one of such stars, found by a Russian amateur astronomer in the ASAS data base.

Digitization of the Moscow Observatory stacks of astronomical plates is accompanied with a search for new variable stars in the resulting electronic archive. Kolesnikova et al. (2010) studied a $10^\circ \times 10^\circ$ field in Ophiuchus. Among 480 new variable stars they discovered in the field, there were 11 high-amplitude δ Scuti stars (HADSs). Additionally, two known variable stars in the field were demonstrated to be HADSs,

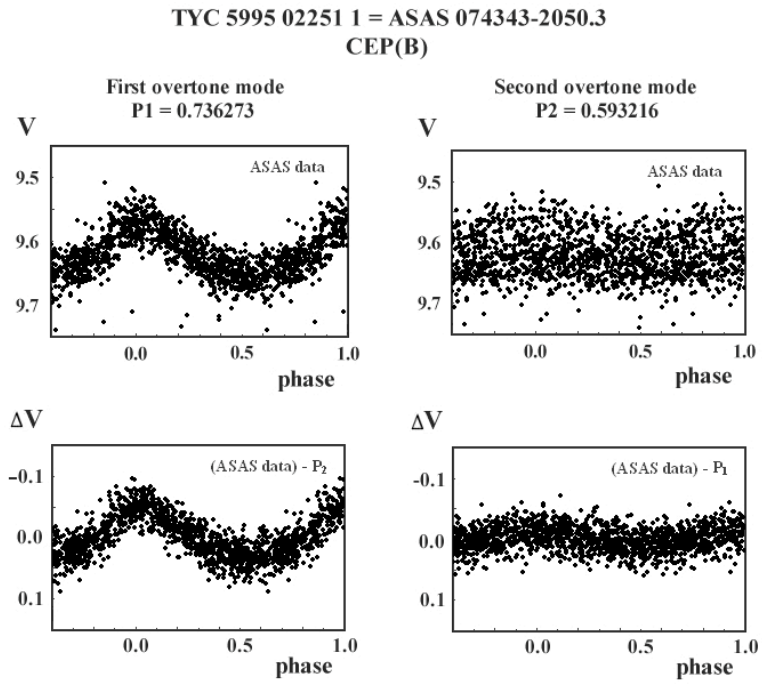


Figure 2 The light curve of the double-mode Cepheid Tyc 5995 02251 1 (Khruslov, 2010).

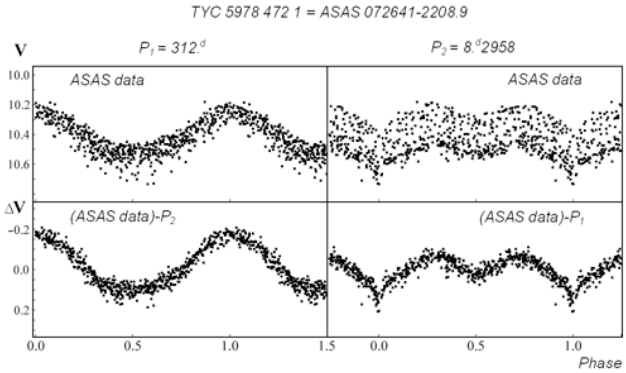


Figure 3 The light curve of the unusual galactic eclipsing star Tyc 5978 00472 1 with a long secondary period (Khruslov, 2011).

making the total of 13. Since the area of the field is less than 0.25% of the whole sky area, the expected number of HADSs for the whole sky should be in excess of 5000, while the total number of δ Scuti stars with amplitudes of at least $0^m.2$ in the GCVS is only 121. Thus, not quite expected selection against short-period stars, with amplitudes even not so low, probably existed in old photographic data.

A similar effect was also detected by Kolesnikova et al. (2010) for the 157 eclipsing stars they discovered in the same field. For all subtypes (Algols, β Lyrae, and W UMa stars), the short-period stars show higher percentage than that in the GCVS, and the long-period stars, lower percentage.

Eclipsing variable stars, considered in the past as one of the best-studied classes of variables, actually can contain pulsating components (many stars of this kind have been recently discovered) or can reveal manifestations of complex effects related to disks, gas flows, etc. Khruslov (2011) found, in ASAS data, an unusual white variable star of our Galaxy that clearly showed eclipses, their period being about 8^d, and rather regular variations with a 312-day period (Fig. 3). In the cited paper, the slow variations were tentatively attributed to the SRD type, though the author remarked on the character of variations being unusual. It turns out, however, that 30 variables of this type were found in the Large Magellanic Cloud; it was suggested to relate their slow variations to precessing disks or to tides in third stars on elliptical, long-period orbits around the eclipsing pair (Mennickent et al., 2003; Buchler et al., 2009).

A very considerable increase of the number of known variables has been recently achieved for stars with rotational brightness modulation (BY Dra and RS CVn types). Apparently, quite a few of them were erroneously classified in the past. In the case of relatively nearby, brighter stars, these types can be identified based on the presence of detectable X-ray radiation. Thus, Berdnikov and Pastukhova (2008) presented a list of 109 probable rotation variables among stars classified as definite or possible Population II Cepheids in the ASAS-3 catalog of new variable stars. In connection with these variability types, we would like to illustrate classification problems that appear for stars with only photometry available. Figure 4, adopted from Solovyov et al. (2011), displays the light curve for a new variable star discovered from CCD photometry, folded with its period of $11^d.34$. The star is faint, and no X-ray identification available so far for this object does not mean anything. It is easy to suggest a wide

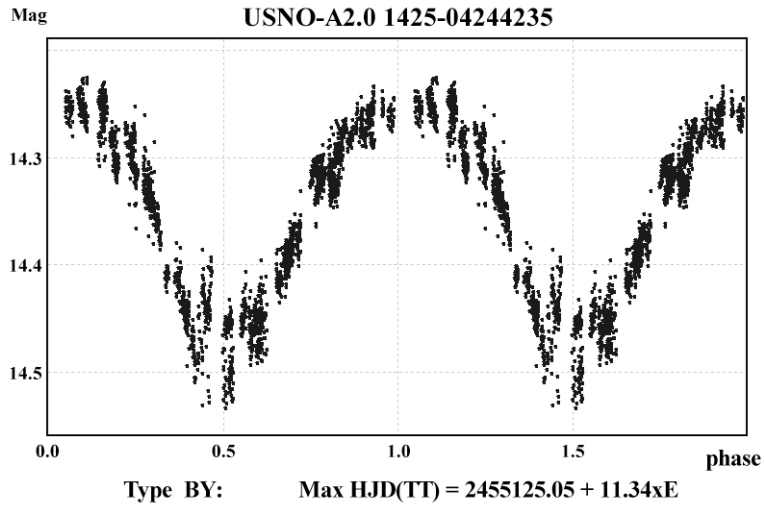


Figure 4 The light curve of the variable star USNO-A2.0 1425–04244235 (after Solovyov et al., 2011): a difficult case for classification.

variety of possible classifications for the star; it can be an eclipsing binary, a pulsating variable, or a rotating spotted star. No existing system of automatic classification is able to establish a reliable variability type for such a star.

4 Conclusions

It seems that the era of traditional variable-star catalogs, based on providing permanent variable-star names to confirmed stars only and on attentive analysis of all available information, comes to its end, despite repeated requests of GCVS users not to discontinue F.W.A. Argelander's naming system for variable stars, in use since the middle of the 19th century. However, information on the already discovered variable stars should be kept somewhere and made available to the community. In future, the GCVS will, beyond doubt, enter a large (billions of stars) general-purpose stellar catalog, with variability information in several columns for each star, along with other data.

Future variability surveys, automatic classification techniques, improved photometric accuracy will completely change our views on the whole ensemble of the Galaxy's variable stars, its statistics, variability types in the very nearest future.

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