GENERAL CATALOGUE OF VARIABLE STARS

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ABSTRACT. The General Catalogue of Variable Stars (GCVS) is a large-scale project undertaken in Moscow since 1946 on behalf of the IAU. After a brief outline of its history, we discuss current problems of variable star catalogues and present our plans for the nearest future, including determination of accurate coordinates for all GCVS stars, new Name-lists, improvements of the classification scheme, *etc.*

Key words: Stars: variable; astronomical catalogues.

1. Introduction

The history of catalogues of variable stars begins as early as 1786, when Edward Pigott published his first list of 12 objects. In the early 20th century, before the 2nd World War, catalogues of variable stars were compiled at the Berlin-Babelsberg Observatory on behalf of the "Astronomische Gesellschaft", a society competing, at that time, with the International Astronomical Union (IAU) as a coordinator of international astronomical research. These catalogues were regularly published till 1942, first by R. Prager and then, after his emigration from nazi Germany, by H. Schneller. Only after the war, the IAU assumed responsibility for variable star catalogues and commissioned this job to two groups in Moscow, the Variable Star Commission of the Academy of Sciences (now the GCVS group at the Institute of Astronomy, Russian Acad. Sci.) and the Variable Star Department of Sternberg Astronomical Institute (now the GCVS group in the Department of Galactic Studies and Variable Stars of Sternberg Astronomical Institute, Moscow University). The leaders of the project in Russia were P.P. Parenago (1906–1960), B.V. Kukarkin (1909–1977), P.N. Kholopov (1922–1988). They were among the founders of the renowned traditions of the USSR astronomers in variable star research. One of the leading representatives of this tradition was the many-year Director of the Odessa Observatory, Prof. V.P. Tsessevich. His studies of RR Lyraes and of young irregular variables, and especially his famous Atlas of Finding Charts, are still widely used by the community of astronomers studying variable stars.

B.V. Kukarkin and P.N. Kholopov initiated the work on the fourth edition of the GCVS in the second half of the 1970ies. This work was finished only comparatively recently, in mid-1990ies. The fourth edition consists of five volumes and contains more than 28000 reliable variable stars of the Galaxy, almost 11000 variable stars in external galaxies, and about 1000 reliable or suspected extragalactic supernovae. The 4th GCVS edition is complimented by the New Catalogue of Suspected Variable Stars (the NSV Catalogue; Kholopov, 1982), with 14810 objects; many of these objects have since become GCVS stars.

The Moscow GCVS team was, on behalf of the IAU, the official center of information on variable stars till 1994, when the IAU discontinued funding for the GCVS project. Nevertheless, we continue our GCVS activity and, though we do see serious problems in our work (to be discussed below), are ready to remain the world center of the variable star catalogues. Our work is supported by the IAU Commissions 27 and 42.

2. GCVS: Traditions and New Trends

The long history of the GCVS has created a number of traditions. The GCVS is intended to include only reliable variable stars that should be sufficiently well investigated, so that they could be attributed to one of numerous variability types of the existing elaborated classification system or declared "unique" variables, not attributable to any type (and maybe future prototypes of new variability types). If a star meets these criteria, it will be included in one of the Name-lists of Variable Stars where it will get its "variable star name", like RR Lyrae (the well-known prototype of pulsating halo stars) or V1343 Aquilae (the famous SS 433). The GCVS names of prototypes and of unique objects are actively used by many astronomers, and thus we are forced to continue the use of the traditional nomenclature of variable stars (R–Z, RR–ZZ, AB–QZ, V335... in each constellation, with the letter J not used) despite its being obviously clumsy.

We have recently published the 76th Name-list of

Variable Stars (Kazarovets et al., 2001), and now the GCVS system includes 37391 "named" variables (this number does not include spurious objects, now proven to be nonexistent, but includes named variables for which further studies led to doubts in variability). Normally, the GCVS team critically evaluates published variability information; in many cases, we used to derive new light elements from published photometric data, to change published classifications according to uniform criteria, etc. Stars with doubtful variability or insufficiently studied variable stars should be included into catalogues of suspected variable stars. Recently, we published a catalogue of 11206 stars suspected in variability since the publication of the NSV catalogue (Kazarovets *et al.*, 1998).

The situation with variable stars has changed rather drastically during the recent decade. Several large-scale space-borne or ground-based projects aimed at automatic discovery of variable stars have been successfully carried out and resulted in discoveries of many thousands of new variable stars. Our traditional individual approach to each star included into the GCVS becomes very difficult to be continued. However, we cannot just drop this tradition and include new stars into the GCVS with the published information accepted "as is". Here our experience with the 74th Name-list of Variable Stars (Kazarovets *et al.*, 1999), specially devoted to new variable stars discovered by the Hipparcos mission (ESA, 1997), teaches us a number of important lessons.

The Hipparcos team initially suggested the authors of the GCVS to give GCVS names to 5665 stars, of which, only (only!) 3157 were then named by us. It may be interesting to note that the selection process, with our usual individual approach to candidate objects, was completed in one month. The majority of the stars not named were included into the Supplement to the NSV Catalog (Kazarovets *et al.*, 1998); a small number of stars were found identical with stars already having GCVS or NSV identifications (and not recognized as such by the Hipparcos team). Hipparcos variables included into the NSV Supplement (a total of 1956 objects) are mostly stars with information insufficient for even more or less reliable determination of their variability types. Of the 3157 newly named Hipparcos variables, nearly 50 percent (1464 stars) have uncertain classification. We have encountered a number of cases of spurious variability in the Hipparcos data: due to wrong identifications in the input catalogue, some stars were attributed absolutely wrong spectral types, resulting in erroneous photometric reductions.

This experience shows some drawbacks of even a very good large-scale automatic survey from the GCVS point if view:

First, observations are scheduled according to reasons far from those of variable-star research. As a result, it is difficult to derive types for stars with certain characteristics. Interesting enough, pulsating variables dominate in the sample of the named Hipparcos variables (2027 of 3157 stars). There are practically no Cepheids among new Hipparcos variables (11 stars have been attributed to all subtypes of CEP, DCEP, or CW variables, and for 10 of them classification is uncertain). The Hipparcos team admits that it was especially difficult to derive, from their data, periods in the typical Cepheid period range. The number of RR Lyraes is also low (28 stars, only 6 of them with certain classification). Contrary, Delta Scuti and SX Phe stars are well represented (97 stars, certain classification for 68 of them). Semiregular and irregular variables give a total of 1692 stars, 54 percent of the sample. Thus, the distribution of the stars of the 74th Name-list over types is rather peculiar.

Second, insufficient attention to identifications makes it more difficult to analyse photometric data. In the Hipparcos project, extensive use was made of SIMBAD data base. This important source of astronomical information contains, however, quite a number of mistakes and incompletenesses in identifications (resulting, in particular, from the fact that, up to recently, many catalogs had very bad positional accuracy). In the process of our work on the 74th Name-list, we revealed more than 500 mistakes or imperfections in SIMBAD identifications.

It is obvious that one of the most important drawbacks of the existing catalogues of "old" variable stars, making automatic identification with "new" variable stars difficult or even impossible, is their low positional accuracy. Formally, the equatorial coordinates presented in the published 4th GCVS edition are given to 1^s in right ascension and to $0'.1$ in declination. Actually, the accuracy of the GCVS coordinates, usually just taken from discovery announcements, can be very different. Till the beginning of the XXth century, many discoverers used to determine quite accurate coordinates for their newly-discovered variable stars, and these coordinates were *rounded* by GCVS compilers. Then, discoveres at Harvard and Sonneberg Observatories, who were most active in the variable star research (at each of the two observatories, more than 13000 variable stars were discovered photographically), began to present only very rough coordinates. Besides rare cases of absolutely wrong positions (errors up to 1° or even more), many *faint* variable stars have positions in error by several arcminutes. We think that drastical improvement of positional accuracy for all "old" GCVS stars is a very urgent task. Many groups in the world are now working in this field. It is now much easier to solve the problem thanks to catalogues like the US Naval Observatory A1.0/A2.0 catalogue (Monet *et al.*, 1998) containing more than 500 million stars with positional accuracy quite sufficient for automatic identifications. (Even larger catalogues begin to appear.)

For variable stars not contained in the A1.0/A2.0 catalogue, it is often possible to use A1.0/A2.0 catalogue objects as reference stars and apply simple astrometric methods to Digitized Sky Survey images. A new and very important tool is the Pixel Server of the US Naval Observatory where one can retrieve images from all existing Sky Survey Schmidt plates, often scanned with better resolution than in the Digitized Sky Survey.

Our group possesses the most complete information on "old" variable stars and is now approaching the problem of accurate coordinates systematically. We have recently prepared a version of the GCVS Volume I (constellations Andromeda–Crux) containing, whenever possible, improved positions and proper motions for variable stars. In this version, sufficiently accurate coordinates are presented for more than 8400 stars. Similar work is in progress for Volume II, improved coordinates have already been listed for about 4600 stars. For identifications, we try to use all published positions, photometric information, finding charts. Similar work on identifications and positions of variable stars is being done by several researchers in other countries, among them C. Lopez, T. Kato, B. Skiff, R. Webbink, G. Williams, and others. Comparison of results makes it possible to reveal mistakes and solve especially complicated cases.

It is to be noted that finding charts are available practically for all variable stars discovered at Sonneberg Observatory, and thus it is possible to find them despite published coordinates being very rough for many stars. On the other hand, several thousand Harvard variables have no finding charts published, and in many cases their identification is not straightforward. Fortunately, the accuracy of published coordinates is, on average, better for Harvard variables than for Sonneberg variables. Some red stars can be identified taking into account their associations with infrared objects of the IRAS catalogue. In our work on the "astrometric" version of the GCVS Volume I, we have been able to recover a number of variable stars on plates of Moscow collection of sky photographs and of the Maria Mitchell Observatory plate collection. Hundreds of variable stars were recovered in the Harvard plate stacks by Drs. M. Hazen and G. Williams, whom we are most grateful for cooperation. They are often able to use ink marks left by discoverers on the plates. Some cases remain very difficult despite serious attempts to solve them.

Another important thing to do for the GCVS team is to improve the classification scheme for variable stars. It is tempting to introduce many new types of variable stars, and we are often urged by experts on particular kinds of variables to do so. But the GCVS team must consider our catalogs as products to be used by a rather wide community of astronomers, and the existing version of the classification system already contains too many types to be easily understood by the users. We would be grateful for suggestions aimed to a clear and *minimally* sufficient system of variable-star classification. Again, our experience with the Hipparcos Name-list teaches us some importan lessons, mainly concerning the classification scheme for pulsating stars, for example:

— Among red stars, we meet probable pulsators not only among supergiants and giants but also among subgiants. For subgiants and especially for dwarfs, it is not easy to decide whether the observed variability is due to rotation or to pulsation. Already, it seems justified to introduce a type for semiregular pulsating red subgiants.

— Among red giants and supergiants, the Hipparcos team derived quite a number of short periods of variability (of the order of days). The light curves do not look very convincing. If real, such periods would cause problems for interpretation and make it necessary to revise the classification of numerous "old" SRB, SRC, LB, and LC stars for which such a behavior was even not looked for. A new type for red giant and supergiant variables with short periods (SRS), presumably overtone pulsators, has just been introduced into the GCVS scheme (Kazarovets et al., 2001).

— Among O–F stars, we meet variables, and probably pulsating ones, not quite satisfying GCVS criteria for DSCT, SXPHE, BCEP, or ACYG-type stars. The Gamma Dor stars, actively introduced as a new type of pulsating variables (*e.g.* Balona *et al.*, 1994), are obviously a related phenomenon (the corresponding GCVS type was introduced by us in the 75th Name-list – Kazarovets *et al.*, 2000), as are the Maia variables, suggested long ago and not understood until recent improvements of stellar opacities.

We are aware of many classification problems besides the short above list concerning only pulsating stars. Thus, most recently he have had to introduce, for the first time in many years, a new type of eclipsing variables (EP, a star eclipsed with a planet).

Having in mind future survey, to be surely expected to result in a still much higher rate of variable-star discoveries, it is important to develop a fully automated approach to preliminary classifications of variable stars on the base of photometric information. This work is now beginning in Moscow.

So far, the Hipparcos Name-list was our first experience with large surveys. Quite a number of stars of other, comparatively minor, surveys (e.g. Takamizawa's program of variable star discoveries) have been included in our regular Name-lists, but new special Name-lists, dedicated to larger surveys, will follow. Here we would like to emphasize that, provided a large survey presents well-structured information on variable stars, such a survey becomes self-sufficient to a considerable degree, a variable star catalogue in itself, and delays with GCVS naming are not so worrying in such cases. Almost perfect is, for example, the pre-

sentation of data in many OGLE publications (see, for instance, Udalski *et al.*, 1994). However, the level of OGLE classification (eclipsers, short-period pulsators, miscellaneous periodic variables) is insufficient for traditions of variable star research. The same holds for the first impressive results of the ASAS project (Pojmanski et al., 2000), presented as a detailed catalogue of several thousand variables, even with light curves and epoch photometry, but again with insufficiently detailed classification. On the other hand, the availability of data from some other surveys (for example, MACHO) becomes a serious problem, to be discussed at the IAU level. The MACHO team members promised, at the IAU Colloquium No. 183 (Taiwan, January 2001), to send us a list of their discoveries, with coordinates, within several weeks; this promise has not been fulfilled, despite reminders. If, in a survey project, thousands of stars are being discovered, but only a small part of them are being announced in a manner sufficient for subsequent identification, the rest of the discoveries are effectively lost.

The delays with special Name-lists for large surveys and the problem of acquiring good coordinates for "old" GCVS stars are obviously interconnected: to be able to check automatically if a newly discovered variable is really a new objects or already a GCVS star, we need good coordinates *both* for the newly discovered stars *and* for all stars of the GCVS.

It is also a problem if a comparatively small survey provides only few observations per star, like the MISAO project. The majority of stars in such surveys, good large-amplitude variables, remain objects for catalogues of suspected variables because it is not possible to classify them with the data available.

Summing up, we can say that the situation with variable stars discovered in large-scale automatic surveys is generally more or less satisfactory from the GCVS point of view, though we are somewhat slow with "special" Name-lists dedicated to such surveys: the results of many surveys are published in a self-sufficient, catalogue-like form. Variable stars discovered individually or in small surveys are regularly included into Name-lists. Since 1999, we give GCVS designations to Novae announced in IAU Circulars within days, upon request from the IAUC editors.

For new GCVS, NSV, and NSV Supplement versions, regularly corrected and improved, with search options, see our web site at
http://www.sai.msu.su/groups/cluster/gcvs/gcvs/

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