# Variable stars in NSVS database: 86 new variables in the region of the Andromeda Constellation

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**Abstract.** A search for light curves with variability is carried out in the area 46 $\deg^2$ in Andromeda in NSVS. The field contains 51955 light curves. 136 variables have been found and 86 of them are previously unknown. Extrapolating the density of the variables in the field to all of NSVS, the total number of variables in the survey is estimated to be 52000 – 61000.
**Key words:** stars:variability

### Променливи звезди в базата NSVS: 86 нови променливи в района на съзвездието Андромеда

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Извършено бе търсене на криви на блясъка с променливост в площадка от 46 $\deg^2$ в съзвездието Андромеда по данни от базата NSVS. Изследваното поле съдържа 51955 криви на блясъка. 136 променливи звезди бяха открити, като 86 от тях са неизвестни досега. Като се екстраполира плътността на променливите в изследваното поле към цялата база, се оценява броят на променливи звезди в обзора на 52000 – 61000.

## Introduction

One of the most extensive sky surveys in recent years is Northern Sky Variability Survey (NSVS, Woźniak et al., 2004a). The light curves of about 14000000 objects with instrumental magnitudes between 8 and 15.5 are included in the database of that survey. The instrumental system is most comparable to the Johnson R band. The observations had been carried out in the period April 1999 – March 2000, covering all of the Northern hemisphere and extended to $\delta = -38^\circ$ to the South.

Usually search of new variables follow a similar procedure: from other sources (IR, X-ray surveys) a sample of stars is been selected by some characteristics and then this selection is checked for variability in NSVS database. This procedure does not make use of the variety of variable stars in the NSVS.

Several studies, based on NSVS data have been published. Preliminary results of ROTSE-I (Akerlof et al., 2000) identified 1781 periodic variables of different types. The catalogue of red variables (Woźniak et al., 2004b) contains the greatest number so far - 8678 variable stars, 6474 of them being newly discovered. Kinemuchi et al. (2006) studied 1188 RR Lyr stars, Wils et al. (2006) identified 785 variables of the same type. The catalogue of Gettel et al. (2006) contains 1022 contact binaries. Otero et al. (2004, 2005a, 2005b, 2006a, 2006b) give information about new eclipsing variables from NSVS. The NSVS database is also used for confirmation and determination of the parameters of the objects from GCVS and NSV catalogues (Kazarovets et al., 2005: Antipin et al., 2005).

Akerlof et al. (2000) estimate the total number of variables to be found from NSVS as 32000, Samus (2006) gives an estimate of tens of thousands expected variables. One of the aims of our research is to estimate the total number of variables, which can be extracted from the NSVS database.

## 1 Search area

As it was mentioned above, the search procedure accepted for the creation of previous catalogues makes use of external to NSVS data to preselect the candidates for variability.

To look for different types of variables we rely upon only internal to the NSVS data. We select an area on the sky and check all of the light curves in this area for variability in the NSVS database. Our test area covers 46 deg$^2$ in Andromeda, its coordinates are: $23^{\rm h}00^{\rm m} \leq \alpha \leq 23^{\rm h}45^{\rm m}$ and $43°30 \leq \delta \leq 49°30$. Galactic latitude is in the range $-10° \div -20°$. The total number of light curves in this area is $N_{\rm total} = 51955$ and every star has between 1 and 4 light curves, the mean value being 1.875 light curves per star. Our search is based on the variability parameter $K$:

$$K = \frac{\sigma_S}{\sigma_E} \tag{1}$$

where $\sigma_S$ is the scatter of the measurements in the light curve and $\sigma_E$ is the median value of the error of a single measurement. Both values are present in the on-line distribution of NSVS data in Sky Database for Objects in Time-Domain - the SkyDOT pages.

There are $N_{\rm limit} = 9083$ light curves in the selected field, with $K \geq 1.5$ at which we cut off our manual examination. We established as detection requirement amplitude $A \geq 0.15^m$ for long period or irregular variability and amplitude $A \geq 0.1^m$ and period $0.05 \leq P \leq 300$ days for the periodic variables.

The period analyses were performed with the program PERANSO (http://www.peranso.com) by ANOVA method, those being most suitable for the light curves with two minima.

## 2 Results

Examination of all $N_{\rm limit}$ light curves revealed $N({\rm var})_{\rm total} = 255$ curves with variability, corresponding to $N_{\rm VS} = 136$ variable stars. The variables, revealed in our search are distributed as follows:

- Variability of the light curves is detected for 28 of total of 56 already known variables from GCVS in the field. There are also 2 other stars from GCVS, which show variability of NSVS light curves, but the amplitude of changes is in the range of measurement errors. The rest 26 variables from GCVS are too bright and have saturated images, making the photometry impossible.
- There are 32 suspected variables in the field, according to NSV, but only 3 of them show variability in the NSVS light curves. Another 11 stars from NSV have NSVS light curves without visible variability. The rest 18 stars from NSV are either too bright for photometry, or their type of variability can not be derived from the NSVS set of observations.
- The Catalogue of Woźniak et al. contains 21 stars, belonging to that field and 13 of them are new variables.
- For 4 of the variables there is unpublished information in on-line VSX database (http://www.aavso.org/vsx). One more variable is present in Dahlmark (1999), and there is also information about another star in the catalogue of Gettel et al. (2006).
- For 86 of 136 variables, detected in our search, there are no previous publications or any information in ADS or SIMBAD and they may be regarded as new variable stars. That number includes: 52 variables of irregular or semiregular types, 24 eclipsing binaries, and 10 periodic variables of different types.

## 3 Analyses

We divide all of the light curves in 19 subsets for the different ranges of $K$ (Table 1). The first column in Table 1 contains $K$ range for the subset. The next column is the number of light curves $n$ belonging to the subset. Columns 3 and 4 contain cumulative

**Table 1.** Light curves statistics in the selected field

| $K$ | $n$ | $N$ | $\log N$ | $n$(var) | $N$(var) | $\log N$(var) | $N_{\rm p}$(var) |
|---|---|---|---|---|---|---|---|
| 100 – 200 | 11 | 11 | 1.041 | 1 | 1 | 0.000 | |
| 50 – 100 | 25 | 36 | 1.556 | 6 | 7 | 0.845 | |
| 20 – 50 | 71 | 107 | 2.029 | 14 | 21 | 1.322 | |
| 10 – 20 | 121 | 228 | 2.358 | 21 | 42 | 1.623 | |
| 8 – 10 | 88 | 316 | 2.500 | 19 | 61 | 1.785 | |
| 6 – 8 | 123 | 439 | 2.642 | 31 | 92 | 1.964 | |
| 5 – 6 | 130 | 569 | 2.755 | 23 | 115 | 2.061 | |
| 4 – 5 | 271 | 840 | 2.924 | 28 | 143 | 2.155 | |
| 3 – 4 | 682 | 1522 | 3.182 | 30 | 173 | 2.238 | |
| 2.6 – 3 | 470 | 1992 | 3.299 | 10 | 183 | 2.262 | |
| 2.2 – 2.6 | 1019 | 3011 | 3.479 | 19 | 202 | 2.305 | |
| 1.8 – 2.2 | 2543 | 5554 | 3.745 | 26 | 228 | 2.358 | 228 |
| 1.6 – 1.8 | 2082 | 7636 | 3.883 | 9 | 237 | 2.375 | 237 |
| 1.5 – 1.6 | 1447 | 9083 | 3.958 | 5 | 242 | 2.384 | 242 |
| 1.3 – 1.5 | 4030 | 13113 | 4.118 | 5 | 247 | 2.393 | 253 |
| 1.1 – 1.3 | 8560 | 21673 | 4.336 | 7 | 254 | 2.405 | 269 |
| 0.9 – 1.1 | 16665 | 38338 | 4.584 | 1 | 255 | 2.407 | 288 |
| 0.7 – 0.9 | 11956 | 50294 | 4.702 | 0 | 255 | 2.407 | 298 |
| 0.4 – 0.7 | 1661 | 51955 | 4.716 | 0 | 255 | 2.407 | 299 |
| Total : | | 51955 | | | 255 | | 299 |

number of light curves $N$ and $\log N$. The number of light curves with variability $n$(var), the cumulative number $N$(var) and its logarithmic value $\log N$(var) are presented in the next three columns. The last column shows the predicted number of light curves with variability $N_{\rm p}$(var) for the respective subset. Data from Table 1 are graphically presented on Fig. 1, as function:

$$\log N(\mathrm{var}) = f(\log N) \tag{2}$$

The relation (2) for lower values of $K$ may be linearly approximated as:

$$\log N(\mathrm{var}) = 1.9041 + 0.1212 \log N \tag{3}$$

Its extrapolation to $N = N_{\rm total}$ gives an estimate for the expected number of light curves with variability in the selected field. Then the predicted total number of the curves with detectable variability is $N_{\rm p}(\mathrm{var})_{\rm total} = 299$. This number corresponds to $N_{\rm VS} = 159$ variable stars, i.e. 23 variables may be detected if the search covers the rest of the $K$ range. Thus, the concentration $\rho$ of variables per light curve in the field appears to be:

$$\rho = \frac{N_{\rm VS}}{N_{\rm total}} = 0.00306 \tag{4}$$

If we accept this approximation to be valid for all NSVS data, and the concentration $\rho$ to be uniform for the survey, then an estimate of the total number of variable stars may be made. There are about $N(\mathrm{NSVS}) = 20000000$ light curves in the NSVS and the total number of the variable stars that can be expected to be extracted from the survey is:

$$N_{\rm VS}(\mathrm{NSVS}) = \rho\, N(\mathrm{NSVS}) \approx 61000 \qquad \text{variable stars.} \tag{5}$$

If we take into consideration only the really detected variables, i.e. $N_{\rm VS} = 136$, then $\rho = 0.00262$ and this number corresponds to total number of variables $N_{\rm VS}(\mathrm{NSVS}) \approx 52000$ and this may be considered as the lower limit to the total number of variables derivable from the NSVS.

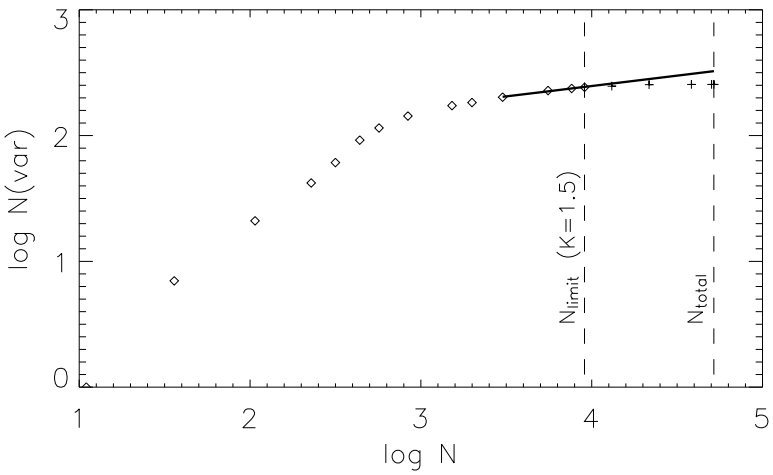


**Fig. 1.** Diagram of cumulative number of light curves with variability in the field. Diamonds represent data for subsets with $K \geq 1.5$, and data with $K < 1.5$ are presented with crosses.

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