Characterization of variable stars using the ASAS and SuperWASP databases

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Abstract. A photographic survey of an area of the sky centred on RA (1900) 12^h 40^m and Dec (1900) $-32°$ $00'$ made by Harvard Observatory in the 1930s identified 108 variable stars. Many of these variables have not been studied since their identification, and therefore there are no published light curves or accurate periods for these stars, and the data in the General Catalogue of Variable Stars (GCVS) is based on the original survey. Sources brighter than V = 14 mag can be found in the ASAS and SuperWASP databases, and can be used to check the classifications and parameters of the variable stars. In particular, in the SuperWASP archive there are over 25 000 observations for many of the sources, making it possible to determine accurate periods, maximum and minimum magnitudes and correctly classify these objects. The methods used to determine the parameters of these variable stars will be described, and results presented of the stars that have been studied.

1. Introduction

High Latitude Field (HLF) 356 for epoch B1900 is centred on right ascension $\alpha_{1900} = 12^h\ 40^m$ and declination $\delta_{1900} = -32°\ 00'$. The field covers the range of RA between $12^h\ 20^m$ and $13^h 00^m$ and Dec between $-27°\ 00'$ and $-37°\ 00'$, an area of about 80 square degrees. J2000.0 coordinates for this position are $\alpha_{2000} = 12^h\ 45^m\ 23^s$, $\delta_{2000} = -32°\ 32'\ 49.7''$ with Galactic coordinates $l = 301.4540°$ and $b = 30.307°$. This region lies way above the Galactic plane in the Hydra/Centaurus region and contains no obvious clusters (open or globular) or any nebulae (emission, reflection, dark or planetary).

Huruhata [1] used 116 plates of HLF 356 taken between 1935 and 1938 on two telescopes to identify variable stars. He reported 108 new variables, and a further 18 stars with ranges of less than half a magnitude as suspected variables. The numbers of each type of star in five classifications are listed in Table 1. More than 50% of the 108 variables are classified as RR Lyrae (hereafter RR) stars.

Many of the stars in Huruhata's list of 108 stars have been given GCVS designations, all others, including the 18 suspected variables, have entries in the catalogue of New Suspected Variables (NSV) [2]. Many of these stars have never been studied in any detail, and some of those that have been subjected to further analysis have been found to be classified incorrectly. Accurate periods for most of this sample of variables have not been determined previously.

2. Data

Data for these stars have been looked for in the All Sky Automated Survey (ASAS) [3] and the Wide Angle Search for Planets (SuperWASP, hereafter SW) [4]. Photometric observations for

Table 1. Numbers of new variable stars reported by Huruhata [1].

RR Lyr	Eclipsing	Short	Mira	Irregular	Total
59	23	6	11	9	108
0	7	10	0	1	18

the brighter stars can be found in the ASAS Catalogue of Variable Stars (ACVS), together with an estimated period and epoch for the light curve, as well as a suggested classification. For some of the fainter stars measurements are available in the ASAS All Stars Catalogue (AASC), but no periods or classifications are provided for these data.

For the SW data, periods are determined but no classifications for the type of variable are provided. The SW telescopes are fitted with filters giving a passband from 400 − 700 nm. The spatial resolution of the data is about 30 arcsec for the smallest aperture used; stars closer than this are blended into one light curve which can lead to the change in magnitude being diluted by a brighter star in the aperture. Because each SW telescope consists of several separate cameras, each with its own response, there can be small differences between data from different cameras. The SysRem algorithm [5] has been used to identify and remove patterns of correlated noise in the data. This produces detrended data which has been used to investigate many of the objects discussed here.

Towards HLF 356 there are about 25 000 SW observations per object. For variables with regular periods of hours to days, the data can be folded on the period to produce phase-magnitude diagrams (PMD), from which it is possible to classify the star. By binning the data at phase intervals of 0.01 there are $\sim 200 - 300$ points per bin, which allows an average curve with small uncertainties to be generated. There are at least four seasons of SW data and mean curves can be fitted to each season. By looking at the relative phase of the maxima and/or minima in the PMD from each season, the period of regular variables can be determined to an accuracy of 10^{-6} d.

At this stage no attempt has been made to clean the detrended data although it is quite clear that there are days when the data is so scattered that it should be discarded. The detrended SW data were run through the programme Period04 [6] to determine if there are any periodicities present in the data. The periods from this analysis were then used to fold the data. In most cases the periods were reliable, but in a few instances, particularly when the source is faint, adjustments were made by looking at the phase over different seasons.

For long period systems, such as Miras and semi-regular pulsators, the detrended data is distorted by the SysRem algorithm and it is better to use the archived SW (which has not been SysRem corrected) or ASAS data. Because neither the periods nor the amplitudes in these systems are constant from one cycle to the next, the data cannot be folded to produce PMDs. For bright sources light curves can be generated but for faint sources it is difficult to determine the reliable data from noisy signals so they have not been studied beyond noting that they are irregular or semi-regular pulsators.

3. Results

The detection limit of the Huruhata [1] survey is around magnitude 16. This is similar to the limit of the SW data, but fainter than the ASAS limit which is ~ 14 mag. Figure 1 shows an example of an SW PMD in which the curve goes below a magnitude of 16. This is the faintest source detected in the SW data. The photometry is not that accurate, but it is possible to determine a period by folding the data, and identify that this is an eclipsing contact binary (EW in the GCVS classification scheme).

There is only one star for which there are ASAS data but no SW data. A PMD of the ASAS data is shown in figure 2. The plot was made using 601 cleaned data points that cover a baseline of 8.7 years. The period has been adjusted from that determined by ASAS to produce the very sharply defined upward phase of the light curve. From the plot it is clear that this star can be classified as RRab.

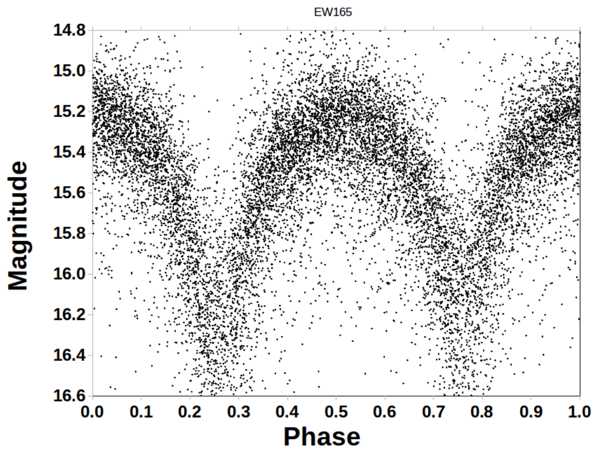


Figure 1. A W UMa-type variable (EW) that was classified as RR in [1].

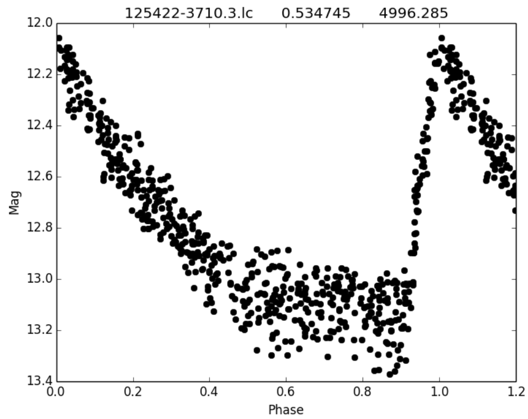


Figure 2. The only star in the sample for which there are ASAS data but no SW data.

For 31 of the 108 variables and 12 of the 18 suspected variable stars there are no data in either ASAS or SW. Their distribution in terms of classification are listed in Table 2. Independent searches have identified one RR and two Irregulars from this list.

Table 2. Numbers of variables for which there is no data in ASAS or SW.

RR Lyr	Eclipsing	Short	Mira	Irregular	Total
23/59	2/23	2/6	1/11	3/9	31/108
0	6/7	5/10	0	1/1	12/18

A few targets had stars that show no obvious variability. In these instances, stars close to the target were looked for in SW to see if any of them showed variability. Figure 3 shows a $10' \times 10'$ field of a POSS2/UKSTU Red image retrieved from the Digitized Sky Survey around one of the target stars. According to Huruhata [1] the target RR star varies between 14.4 – 15.2 mag. As indicated on the chart, only a non-varying pair of stars is at the specified position. Huruhata [1] makes no mention of this star being a binary (as noted for other stars). Nearby stars for which there are SW data are circled in blue and their SW magnitudes indicated. Stars that are not recognised by SW are indicated by red circles.

The 70 systems for which positive identifications have been made and periods determined include 35 RR, 21 eclipsing and 5 Miras. Light curves of stars showing variability but for which Period04 could not identify any reasonable periods have been classified as Irregulars. Two of these are known dwarf novae and one of them appears to be a long period W Vir-type star. The GCVS classification of this star is CWA. For long period variables and semi-regular pulsators (Irregulars) the ASAS data often provide a better light curve than the SW data. An example of the ASAS light curve of one of the Miras in this sample is shown in figure 4.

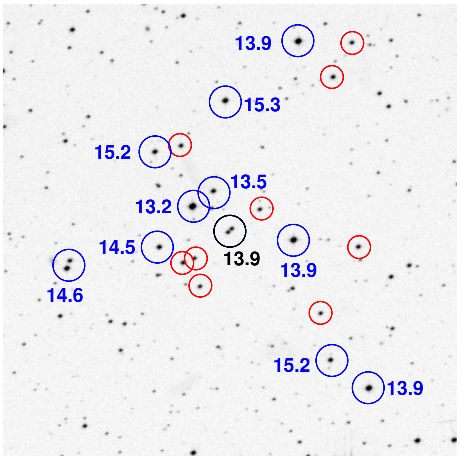


Figure 3. A 10′ × 10′ field around a target star. The numbers indicate the SW magnitude of stars showing no variability.

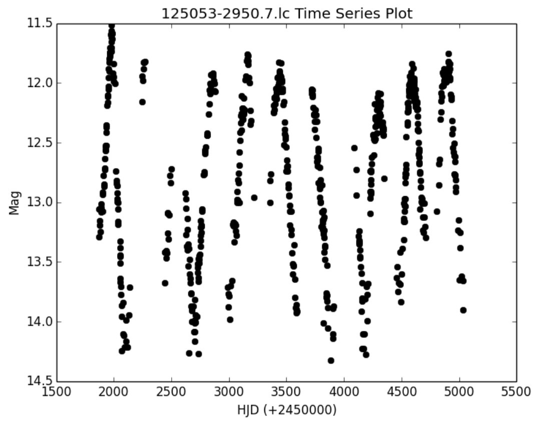


Figure 4. The light curve of a Mira made using ASAS data. The amplitude of the peaks vary from one cycle to the next, and the period is not constant.

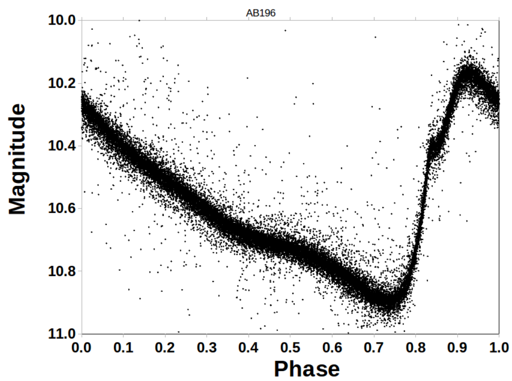


Figure 5. The PMD of an RRab type showing a rapid rise and slow decline with a hump at phase 0.7 and a bump at phase 0.9.

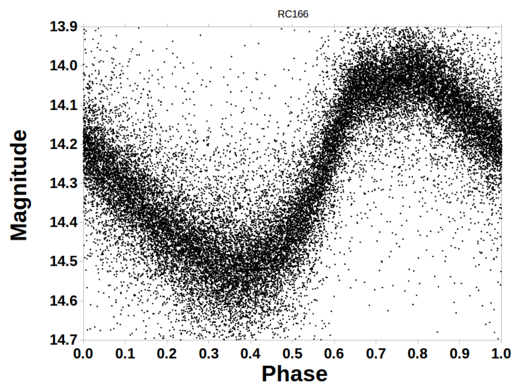


Figure 6. The light curves of RRc types are nearly sinusoidal. There is a bump in the light curve just before maximum.

Of the 35 RRs identified, 29 are type RRab and 6 are RRc types. The light curves of RRab types have an asymmetrical shape with a rapid rise and a slow decline. Features such as humps (at $\phi \sim 0.7$) and bumps (at $\phi \sim 0.95$) can be seen in the PMD for many of the RRab systems (see figure 5), and several RRc types also show bumps just before the maximum, as shown in figure 6. The nearly sinusoidal shape of the light curve together with its period identifies this as RRc.

The eclipsing binaries are made up of 7 detached (EA), 1 semi-detached (EB) and 13 contact (EW) systems. One of the EW stars was not part of Huruhata's original list, but it lies within the field studied and, with a magnitude of 9.6, should have been detected.

In figure 7 the light curve of a detached eclipsing binary system is shown. The SysRem data were used to generate the PMD shown on the left, and ASAS data for that on the right. From the plot on the left, the magnitude of the system appears to be varying from one season to the next. The period of the system is close to 1 day and therefore less than half the cycle can be observed during the course of a night. Because the phase changes slowly during the course of a season, only a part of a cycle can be observed. For example, in one season only the secondary eclipse was visible but in other seasons part of the primary eclipse was observed. The SysRem algorithm tries to correct the light curve for changes from night to night and season to season using a mean value of the curve. Because the mean changes with the season, the corrections have shifted the curves so that they do not match up.

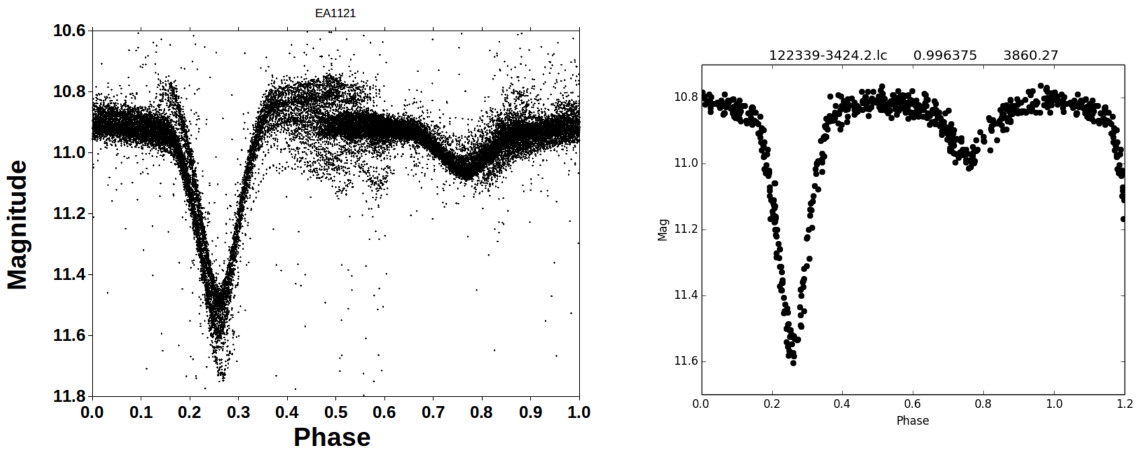
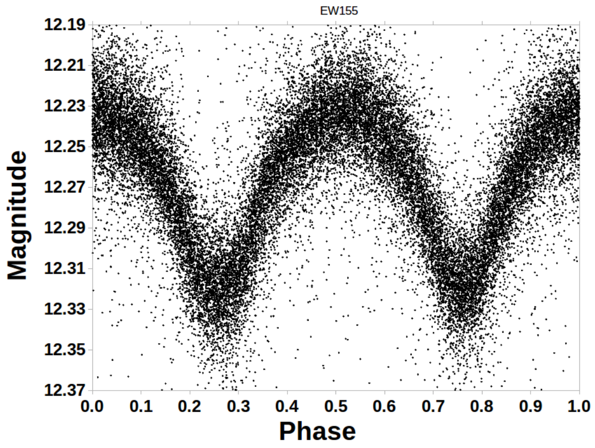


Figure 7. PMDs made from SW (left) and ASAS (right) data for an EA system with a period $P \sim 1$ day. The SysRem algorithm has affected the SW data.

The light curve amplitude of contact binaries is a maximum when the orbital inclination is edge-on ($i = 90°$), with a typical value of $\Delta V = 0.8$. The shape of the light curve changes with inclination, becoming more sinusoidal as the inclination decreases. Most of the EW systems in this sample have ΔV in the range $0.8 - 0.3$ mag. A light curve with a small ΔV but a characteristic EW shape suggests a system with a third body whose light is not part of the variable system. An example of a system whose variations are anomalously small is shown in the left-hand panel of figure 8. The light curve has been folded on a period of 0.362716 d to produce the PMD shown in the diagram. This is clearly an EW system but for a star with a magnitude of 12, the variations go from a maximum of 12.22 to a minimum of 12.32, i.e. $\Delta V \sim 0.1$. According to the NSV catalogue the star labelled NSV on the finder chart is the variable. A Fourier analysis of the SW data for the NSV star does indicate a periodicity of 0.362716 but the amplitude is less than 0.1 mag. The folded SW data for the star labelled 2MASS has a larger amplitude than NSV, but the variations are small and not sinusoidal, suggesting contamination from a third star rather than an inclined system.

To investigate which star is varying, observations were made through a V-band filter with an SBIG ST9E CCD camera attached to the 35 cm Schmidt-Cassegrain telescope in the Unisa Observatory. The system has a field of view of about $9' \times 9'$ which is slightly smaller than the finder chart shown in figure 8. Differential photometry was done on several of the stars, in particular on those marked NSV, 2MASS and the one labelled with the red arrow. From the Unisa Observatory observations it can be shown that the variable is the star labelled with the red arrow, which is fainter than the other two stars. It is not possible with the SW system to



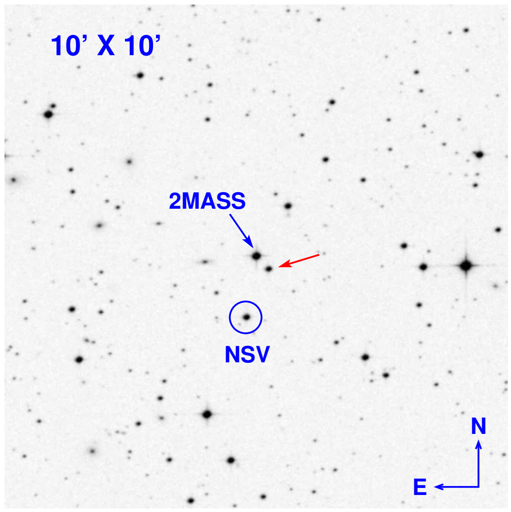


Figure 8. The amplitude of the EW variations are too small for a 12th magnitude star. The coordinates given in the NSV catalogue for this variable are incorrect. The variable is indicated by the red arrow on the finder chart.

resolve the 2MASS and variable star spatially, but it appears that some of the flux from the variable is even creeping into the NSV star observations, producing the small variation that was detected.

Several other stars in the sample display similar properties to this, i.e. the amplitudes of the variations are too small relative to the magnitude of the star, suggesting that the variable is a faint star in the aperture being swamped by light from a bright star. Further observations will need to be done on these systems to identify the variable stars and determine their apparent magnitudes.

4. Conclusion

Using data from the ASAS and SW projects the light curves of 108 variable stars and 18 suspected variables in HLF 356 have been investigated. For 70 systems data are available in ASAS and/or SW, making it possible to determine the period and classification of RR, eclipsing and Mira variables. Data for several irregular variables have also been retrieved, but this data have not been processed yet.

References

[1] Huruhata M 1940 *Harvard College Observatory Bulletin* **913** 14–17
[2] Kukarkin B V and Kholopov P N 1982 *Moscow: Publication Office "Nauka"*
[3] Pojmanski G 2002 *Acta Astronomica* **52** 397–427
[4] Pollacco D L *et al* 2006 *PASP* **118** 1407–18
[5] Tamuz O, Mazeh T and Zucker S 2005 *MNRAS* **356** 1466–70
[6] Lenz P and Breger M 2005 *CoAST* **146** 53–136