Astron. Astrophys. 346, 537–541 (1999)

ASTRONOMY
AND
ASTROPHYSICS

Research Note

Monitoring of LPVs with an automatic telescope I: five new short period semiregular variables

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Received 23 September 1998 / Accepted 9 April 1999

Abstract. We present light curves of five short period variables of spectral type M. They are the first result of our monitoring program of LPVs with an automatic telescope. The stars vary semiregularly on time scales of about 35 days and with small visual amplitude. It is shown that the Fourier analysis is only of limited use for this kind of stars. We conclude that this type of variability is more common among M giants than previously thought, and we briefly discuss these variables with the shortest periods among the SRVs.

Key words: stars: late-type – stars: oscillations – stars: variables: general

1. Introduction

Variability in brightness is a characteristic feature among stars associated with the Asymptotic Giant Branch (AGB). Variations are observed on time scales of 10 to 1000 days (long period variables, LPVs). These variables have been classified into miras, semiregular variables (SRa and SRb, in the following SRVs) and irregular variables (Lb). While the light curves of a large number of miras have been observed over many years (e.g. Mattei et al. 1990), only very few long time-series with high photometric accuracy and good time resolution of variables with shorter periods (SRVs, Lbs) exist (e.g. Percy et al. 1994). Variations are known only very roughly for these stars. The light variations, on the other hand, could provide important information both on the mechanism of pulsation as well as the stellar structure.

This lack of light curves of short period SRVs was the starting point for a monitoring program on SRVs and irregular variables with the University of Vienna Twin Automatic Photoelectric Telescope (APT) at Fairborn Observatory in Arizona. A description of these telescopes is given in Strassmeier et al. (1997). Automatic telescopes are very helpful in providing light curves of small amplitude variables with high photometric accuracy (typical error of 6 mmag) and time resolution. In our case typically one datapoint is obtained every second night. This program is now running for more than 1.5 years, long enough to deduce first reliable results for these types of variables. The sample consists of 28 SRbs and 14 Lbs. Observations are done mainly in Bessell V & I filters with a few objects observed in Bessell B & V. A publication of the results for the program stars is in preparation. As a byproduct some comparison stars were identified as unknown variables.

In this paper we present as a first result from our APT-program light curves of five comparison stars that turned out to be variable. From these light curves we deduced parameters of the variation like amplitude and a timescale of variability. Three of these objects have been detected independently as variables by the HIPPARCOS mission (ESA 1997). Therefore these objects received variable star names in the mean time (HV Lib, MZ Vir and V4401 Sgr). For the other two stars (HD 113410 and HD 200512) no variability has been reported before. Both objects can be found in the TYCHO catalogue (ESA 1997). While no indication of variability is noted for HD 113410, HD 200512 is a suspected variable (field T48 = W in the TYCHO catalogue).

HIPPARCOS has discovered a large number of new variable stars with small visual amplitudes. However, most of the variables were observed by the satellite with a rather bad sampling in time. While HIPPARCOS typically observed one star several times within one day, a time span of several weeks passed before the star was observed again. This fact allowed the discovery of variations on a time scale of hours (de Laverny et al. 1998), but it reduced the chance to attribute the cool red objects to a distinct class of variables and to deduce reliable parameters of the light change (Lebzelter et al. 1995). However, this was not the main goal of the HIPPARCOS mission.

It is the aim of this paper not only to present the parameters describing the light variation of five variables, but also to focus on these red, small amplitude and short period variables in general, for which no or only insufficient information on their variability is known up to now.

2. Individual objects

The light curves of MZ Vir, HV Lib, V4401 Sgr and HD 113410 are plotted in Fig. 1. HD 200512 has been observed at a different time and is therefore plotted in Fig. 2. Stellar parameters and pa-

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rameters of the light change deduced from our observations are listed in Table 1. Additional data were taken from the HIPPARCOS (ESA 1997) and IRAS (1988) catalogue (see references therein).

A misidentification by the automatic telescope or influence of the measurement by a nearby object can be excluded as none of these objects is located in a crowded field in the sky or has a star of comparable brightness nearby. Brightness of the stars was determined using a second comparison star. These check stars were either early type K stars or G stars. All of them were observed by HIPPARCOS without detection of any variability.

At a first glance all light curves show more or less irregular light changes suggesting that these stars are either semiregular or irregular variables. However, the light curves show a number distinct maxima and minima. These were used to estimate a timescale of variability. None of the objects showed a single distinct period but a period range around 30–60 days. Therefore I will use the term period in the sense of ‘timescale of variability’ in this context. A Fourier analysis of the data was done to see, whether the derived timescale could also be found in the Fourier spectrum. Our Fourier analysis algorithm of unequally spaced data has been discussed by Deeming (1975). We used it coded in an improved way as proposed by Kerschbaum (1988). An example for the result of a Fourier analysis is given in Fig. 3 for HV Lib. It is obvious that the same problem occurs noted already from visual inspection of the light curves. A large number of peaks of comparable height make the identification of a single period difficult. Several of these peaks are secondary maxima of a real peak as can be seen from the spectral window (Fig. 3, upper panel). However, this is what one would have expected due to the large irregularities and asymmetries in the shape of the light curves. Therefore the Fourier analysis alone is not an appropriate tool to derive a period for these kinds of objects. But it provides a possibility to check or quantify periods identified by measuring the time difference between two observed maxima or minima. In this paper I will use it for this aspect only. Analyzed with these two approaches the four stars gave the following results:

MZ Vir: The amplitude of the variation is quite large. The light curve shows a lot of bumps and other irregularities over the whole time of observation. From measuring maxima and minima we derive a period of 61.6$\pm$7 days. We thereby excluded some small ‘intermediate’ maxima, which would suggest half the period. A regularity of the occurrence of these intermediate maxima could not be found. Fig. 4 (top panel) shows the result of the Fourier analysis for MZ Vir. The highest amplitude is reached for a period of 69 days, close to the value derived by visual inspection. A further peak is visible around 35 days which coincides with the variations found from to the small ‘intermediate’ maxima.

HV Lib: For this star determination of a typical timescale is very difficult. The amplitude of the light cycles changes strongly making a clear separation of different cycles problematic. Therefore only a rough estimate of the period was done giving about 45 days. It is interesting to note a significant shift in the mean brightness of the star after the break in observations where the telescope was closed. This might indicate a secondary period with a much longer time scale as discussed below. As expected the Fourier analysis (Fig. 3 and 4) does not really help to improve the result. The highest peak is found at 735 d. This might be due to a possible secondary period, but it is badly resolved and close to the total time covered by the observation. Still this long period peak is not that expressed in the other three objects. It also has the same amplitude as the mean brightness difference before and after the break in observations. The second highest peak lies at 48 days, i.e. close to our estimated value. However, the amplitude of this peak does not differ much from peaks at 37 and 90 days. Unless a longer time series of observations reveals a dominant period, this star has to be classified as irregular.

V4401 Sgr: The number of maxima and minima, which can be clearly identified, is small. 4 maxima and 2 minima were chosen resulting in a mean period of 25$\pm$7 days. Close to this value two peaks can be found in the Fourier spectrum (Fig. 4) at 23 and 31 d. The amplitude of all peaks is very small. Compared with the other three objects, the time coverage is less dense for this star. The spectral window is therefore not very clean so that the detection of the correct frequencies is difficult.

V4401 Sgr is the only object of our sample with several notations in the literature. Eggen (1976) suspected the star to be variable. From an inspection of the HIPPARCOS light curve one might suspect an overlapped variation on a significantly longer timescale indicated by a change in mean brightness between JD 2448000 and 2448500. Such a variability is not found in our observations. The HIPPARCOS catalogue lists furthermore variations on a very short time scale of 3.4 days for this star.

HD113410: Maxima and minima are clearly defined in this object. Five maxima and five minima were selected giving a mean timescale of variability of 32.5$\pm$6 days. Maxima and minima give very similar results. Fourier analysis shows three periods with comparable amplitude: 25, 27 and 39 days. The peak at 27 days is thereby probably influenced by the peak at 25 days.

HD200512: As the time of observation of this object is slightly different from the other four stars it is plotted separately in Fig. 2. Variations are on a short time scale but maxima and minima are clearly defined. 8 maxima and 5 minima were selected giving a mean period of 23.4$\pm$6 days. The amplitude is the smallest found among the five objects investigated. The Fourier analysis gives two peaks at 26 and at 30 days, respectively, both of them not very well expressed. The mean brightness of this star seems to vary slowly over the time observations were obtained. Therefore we suspect the presence of a second, significantly longer period. For this star we have also information on the flux in the Johnson I filter relative to the comparison star. The I-amplitude is approximately by a factor of 2 smaller than the V-amplitude.

For these five stars, which are probably quite good examples of short period semiregular and/or irregular variables, the results of Fourier analysis and visual inspection lead to similar results in the way that periods from visual inspection are detectable as those peaks in the Fourier analysis, which show the maximum amplitude. But as noted above the large number of

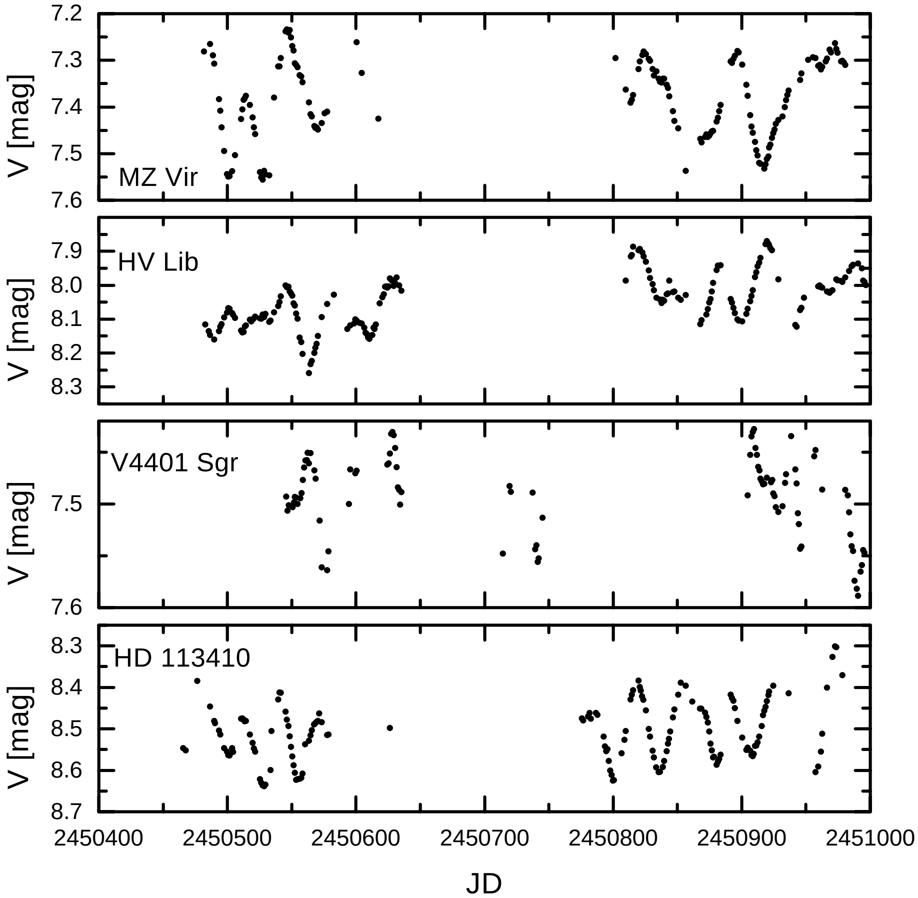

Fig. 1. V light curve of MZ Vir, HV Lib, V4401 Sgr and HD 113410.

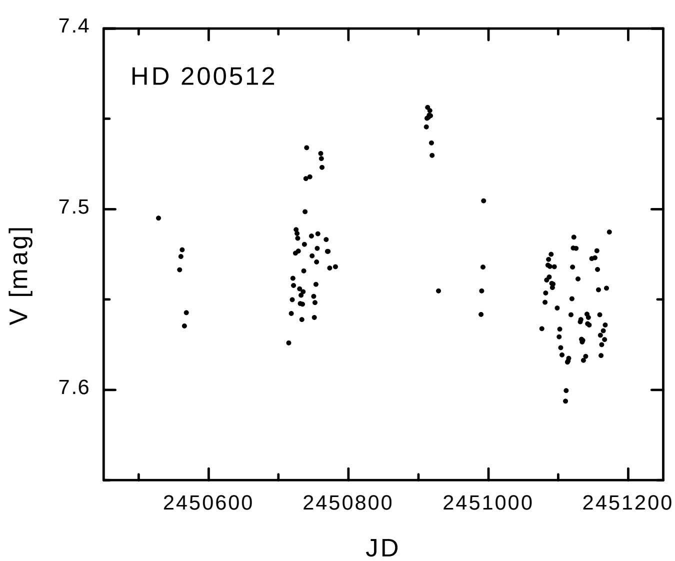

Fig. 2. V light curve of HD200512.

peaks does not allow to draw a conclusion on the period from the Fourier spectrum alone for the presented set of data. Light curve parameters for all four objects are summarized in Table 1. The period in brackets is thereby the result of the highest peak in the Fourier spectrum (except for HV Lib). The variability amplitude given in the HIPPARCOS catalogue differs slightly from our value in the case of HV Lib and MZ Vir, while good agreement is found for V4401 Sgr.

A separation between semiregular and irregular (Lb) variables is difficult for these objects. As a typical timescale of the variations can still be defined we would suggest to classify MZ Vir, V4401 Sgr, HD 113410 and HD 200512 as semiregular variables. On the other hand first results from our monitoring program of irregular variables classified by the General Catalogue of Variable Stars (GCVS, Kholopov et al. 1985–88) show that such typical timescales can be found for several Lbs, too. Therefore we suspect that a division in semiregular and irregular is not meaningful. This is consistent with results from near infrared photometry by Kerschbaum et al. (1996) showing that the O-rich Lbs are undistinguishable from SRVs with the same chemistry. An investigation of this question with a larger sample of Lbs is planned.

3. The shortest period SRVs

It is interesting to note that the time scale of the variations of all four objects is comparable. The GCVS lists a number of M-type variables in this period range with comparable V amplitudes of a few tenth of a magnitude. These variables form the short period end of the period distribution of SRVs. According to the definition by Kerschbaum & Hron (1992) most of them can be classified as ‘blue’ semiregular variables which is expressed

Table 1. Stellar properties and light curve parameters for the four new variables. Light curve parameters were derived from the data presented in Figs. 1 and 2. Column 6 gives the variability amplitude listed in the Hipparcos catalogue. The periods given in column 5 have to be seen as typical time scales of the variation, where the period in brackets is the result of the Fourier analysis (see text).

variable name	HD	HIP	IRAS	period [d]	visual ampl.	HIP ampl.	spectral type	IRAS [12]−[25]
MZ Vir	125357	69987	14165−1410	62 (69)	$0\overset{\mathrm{m}}{.}25$	$0\overset{\mathrm{m}}{.}165$	M2/3III	−1.51
HV Lib	132614	73445	14577−1140	45 (48)	$0\overset{\mathrm{m}}{.}25$	$0\overset{\mathrm{m}}{.}346$	M...	−1.46
V4401 Sgr	171394	91135	18324−1918	25 (23)	$0\overset{\mathrm{m}}{.}12$	$0\overset{\mathrm{m}}{.}101$	M3/4III	−1.48
	113410		13009+0510	33 (27)	$0\overset{\mathrm{m}}{.}25$		M...	−1.55
	200512		21009+2415	23 (30)	$0\overset{\mathrm{m}}{.}07$		M...	−1.41

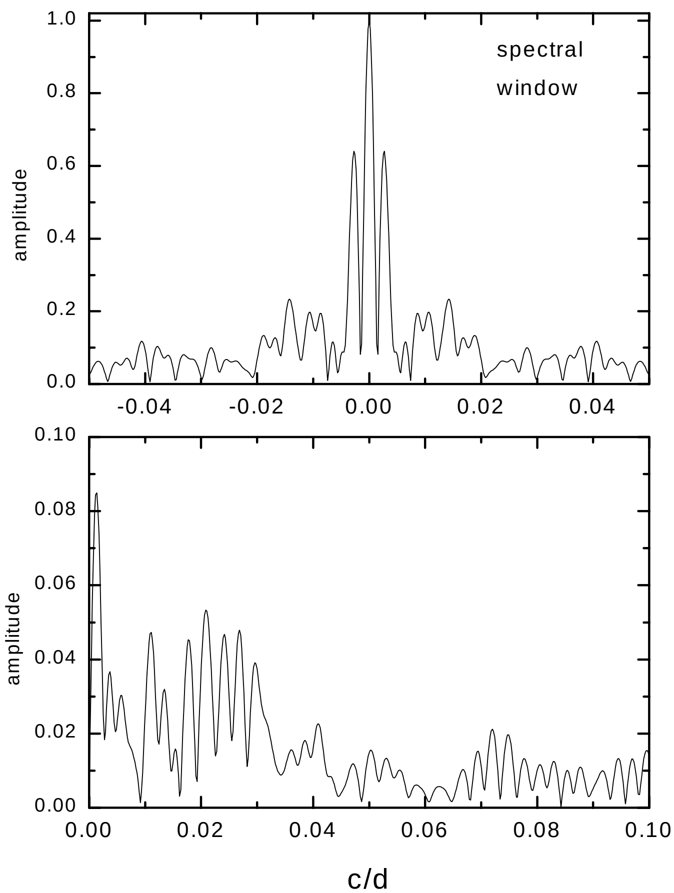

Fig. 3. Results of Fourier Analysis of the lightcurve of HV Lib. Upper panel: Spectral window. Lower panel: amplitude spectrum in cycles per day.

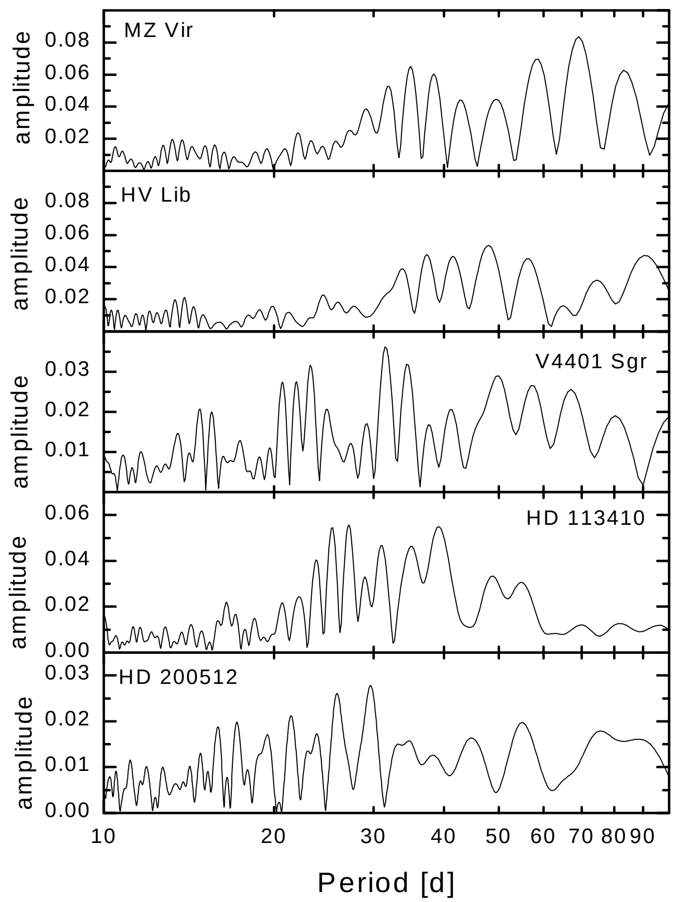

Fig. 4. Result of the Fourier Analysis of the light curve of HV Lib, MZ Vir, V4401 Sgr and HD 113410. In these plots the X-axis was transformed to period in days to provide a better overview.

in their IRAS [12]−[25] colour. This is also the case for the five new variables presented here. The values of the five new variables is in coincidence with the mean value of [12]−[25] of $-1\overset{\mathrm{m}}{.}42$ found for the 45 SRVs listed in the GCVS4 with short periods (≤ 50 days) and good IRAS flux quality. In the IRAS two colour diagram (van der Veen & Habing 1988) these short period SRVs can therefore be found in region I, i.e. oxygen rich stars with Rayleigh Jeans type spectra (LRS classes 17,18) and no circumstellar dust. These objects are thought to be on the RGB or the early AGB (Kerschbaum & Hron 1992). This scenario is supported by Lebzelter & Hron (1999), who note that these variables are not expected to be on the thermal pulsating AGB as no ^{99}Tc is found in their spectra. The variability observed in these stars might therefore be characteristic for the RGB or early AGB phase.

However, variations with periods around 35 days are not the only observed light changes in these stars. A secondary and significantly longer period of the order of 1000 days might be visible in three stars of our sample (HV Lib (our data), HD 200512 (our data), V4401 Sgr (Hipparcos data)). Present data are not sufficient to describe this variation more exactly. Such additional variations have been observed in several SRVs (e.g. Houk

Table 2. Distribution of the HIPPARCOS new unsolved variables. Column 2 gives the absolute number and column 3 the percentage relative to all unsolved variables. Column 4 lists the mean amplitude of the variation.

Spectral type	number of objects	%	mean amplitude
O	15	0.4	$0\overset{m}{.}086$
B	582	14.2	$0\overset{m}{.}098$
A	312	7.6	$0\overset{m}{.}099$
F	342	8.4	$0\overset{m}{.}129$
G	297	7.3	$0\overset{m}{.}130$
K	736	18.0	$0\overset{m}{.}099$
M	1695	41.5	$0\overset{m}{.}132$
C, R, N	32	0.8	$0\overset{m}{.}287$
other	9	0.2	
unclassified	66	1.6	

1963, Percy et al. 1996). Unfortunately, up to now investigations dealed mainly with SRVs in the period range between 60 and 200 days, but Houk (1963) reports a secondary period of 1500 days for KQ Oph, a semiregular variable with a period of 30 d. As the period for many of the short period SRVs has been determined from quite short time series (Lebzelter et al. 1995), it is not clear whether this is a more common phenomenon. More data and longer time series are necessary to decide which period is important for which aspect of the variability.

New discoveries like the ones reported in this paper show that a variability with periods around 35 days and small amplitudes might be significantly more common among objects in region I of the IRAS two-colour-diagram than previously suspected. Even among bright M giants variables are found frequently (e.g. Eyer & Grenon 1997, Percy & Fleming 1992, Schmidt 1996, this paper). Jorissen et al. (1997) showed that variability with amplitudes of more than 6 millimag starts at spectral type K and gets more frequent towards later spectral type.

This is also supported by the distribution with spectral type of the unsolved variables from the HIPPARCOS mission (Table 2). HIPPARCOS detected 4086 new unsolved variables. More than 40% of these variables are M-stars. 928 of them have been classified as giants and 720 have no luminosity classification. The HIPPARCOS catalogue classifies 346 of these objects as semiregular (SR). The mean amplitude of the M-type unsolved variables is in agreement with values found for the variables in this paper. An extension of the known group of SRVs with periods below 50 days can therefore be expected.

However, like for their evolutionary status it is not clear whether the variations observed for these variables are really due to (radial) pulsation of these stars or other mechanisms not yet understood (Jorissen et al. 1997). These mechanisms could also be relevant for AGB variables with longer periods where small additional variations on short time scales are observed (e.g. Hinkle et al. 1997). In this context very short timescale variability (as suggested by Hipparcos data for V4401 Sgr) would be very interesting, too.

These short period objects could also be relevant for modeling asymptotic giant branch stars. For numerical and physical reasons (growth rates) it is better to start such models at the blue border of the instability strip which would allow the setup of a hydrostatic model as starting point which could then be developed on to stellar parameters typical for Mira-variables (Feuchtinger 1999). Therefore a detailed analysis of stars close to the border of the instability strip will provide important input parameters for these models.

Acknowledgements. This APT observing program is done in collaboration with J. Hron and F. Kerschbaum and supported by the *Fonds zur Förderung der wissenschaftlichen Forschung* under project number S07308-AST and S07301-AST. The author wishes to thank T. Granzer for support with the APT. Special thanks to F. Kerschbaum for help with the Fourier analysis, and to M.Breger for enlightening discussion. This research has made use of the Simbad database operated at CDS, Strasbourg, France.

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