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A SEARCH FOR PERIOD CHANGES IN LONG PERIOD VARIABLES

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Asymptotic Giant Branch (AGB) stars are objects of low or intermediate mass in their final stage of stellar evolution. This is a short but decisive phase, where the star is producing a variety of heavy elements and loses mass at a high rate. Most AGB-stars are showing long period variability on time scales of a few ten to a few hundred days and visual amplitudes up to several magnitudes. This class of pulsating stars is called the Long Period Variables (LPVs).

The evolution and internal structure of AGB stars is dominated by a hydrogen and a helium burning shell which alternate in providing the major part of the stellar luminosity. This cycle, named thermal pulse, has a typical timescale of 10^5 yr. During a cycle, luminosity, temperature, radius, and surface composition can change as a reaction to the processes in the stellar interior (e.g. Vassiliadis & Wood, 1993). The most easily accessible way to study such a cycle is the change in period (due to a radius change) as long time series exist for a large number of galactic LPVs. Indeed, candidates for period changes have been detected by various authors (Wood & Zarro, 1981; Lloyd, 1991; Percy & Au, 1999; Templeton et al., 2005).

Such studies are typically based on long, more or less continuous time series of visual observations provided by observatory publications or by amateur astronomers. These long light curves are then analysed for possible period changes e.g. by using an $O-C$-diagram, wavelet analysis (e.g. Hawkins et al., 2001) or other methods (e.g. Merchan Benitez & Jurado Vargas, 2000). Systematic period changes can be noticed on timescales of a few ten years.

In this paper we want to explore a somewhat different approach. Many LPVs have been detected and characterized in the first decades of the 20$^{\text{th}}$ century. The beginning of the 21$^{\text{st}}$ century sees a number of automatic surveys during which sets of typically several light cycles of photometric data of the same variables are obtained and automatically analyzed. This means that we have two sets of monitoring data separated by 60 to 100 years. By comparing the old periods with the newer ones should allow to detect candidates for a period change. We note that small irregular changes of the period length of a few percent are well known to occur in long period variables (cf. Wood & Zarro, 1981 and references therein). A relation to the thermal pulse cycle is less likely in these cases. Some stars show a switching of the pulsation mode from time to time of which the origin is not understood

Table 1. Candidates for period-changing Miras.

Name	GCVS period	rev. ACVS period	ΔP [%]	ΔT	Remark
BF Mon	283 d	151 d	−47	25000 d	
BG Hya	262 d	305 d	+16	24000 d	
V433 Cen	367 d	179 d	−51	24000 d	
ES Cen	174 d	352 d	+103	28000 d	
AX Mus	99 d	115 d	+16	27000 d	*
AX Lib	115 d	221 d	+92	24000 d	
CO Sco	176 d	149 d	−15	36000 d?	
V2121 Oph	158 d	296 d	+87	10000 d	*
ZZ Oph	205 d	303 d	+47	27000 d	
BD Ser	134 d	209 d	+56	29000 d	
WY Ser	399 d	195 d	−51	26000 d	*
V3190 Sgr	194 d	226 d	+16	38000 d	*
V2030 Sgr	283 d	159 d	−44	27000 d	
V3343 Sgr	134 d	122 d	−9	16000 d	*
UX Aql	375 d	188 d	−50	29000 d	
CX Sgr	211 d	179 d	−15	35000 d	
AM Sgr	95 d	126 d	+33	36000 d	
BM Sgr	403 d	201 d	−50	37000 d	*
V540 Aql	309 d	165 d	−47	24000 d	
EK Aql	152 d	259 d	+70	37000 d	
TX Cap	129 d	199 d	+54	25000 d	
UV Tuc	310 d	160 d	−48	28000 d	
RX PsA	366 d	151 d	−59	24000 d	

yet (Kiss et al., 1999). These aspects have to be considered when interpreting observed period changes.

For our study we selected the ASAS catalogue of variable stars (ACVS, Pojmanski, 2000) which is based on a monitoring of the whole Southern sky up to δ =+28° over a time span of about 3000 days between 1997 and 2005. Light curves of most variables brighter than V=15 mag as well as automatically determined periods and variability classes are available. We cross-correlated this catalogue with the General Catalogue of Variable Stars (GCVS, Samus et al., 2009) using stellar coordinates with a search radius of 0.1 arcminutes. Within this sample we identified 109 stars classified as miras in the ACVS where the ASAS period deviates by more than 9% from the GCVS value (stars with no GCVS period were not considered). For these stars we re-determined the period from the ASAS data and rejected 59 stars where either the corrected period was close to the GCVS value or the ASAS data were of low quality.

This left us with 50 stars to which we added 11 stars selected in the same way from the list of stars that were classified as 'MISC' in the ACVS, but as Miras in the GCVS. For this sample, we looked up the reference used for the period value given in the GCVS. 18 of these literature sources were not accessible for us and we also did not find any further usable reference. In 16 cases, we found that the published light curve data could be equally or even better fitted using the period derived from the ASAS data. Sometimes the authors noted already that the derived period is uncertain and could for instance be doubled or halved as well, which would bring it into agreement with the ACVS value.

This left us with 27 stars for which the difference between the independently determined periods from the GCVS and the ACVS makes them candidates for a period change.

Among these 27 targets we detected 4 stars that have been known before to be Miras with a variable period: RU Tau (Percy & Au, 1999; Templeton et al., 2005), BH Cru (Templeton et al., 2005; Walker, 2009), ES Del (Watanabe, 2001; Templeton et al., 2005), and RT Vel (Lysaght, 1989). This is a nice confirmation that our method is capable of detecting Miras with period changes. The remaining 24 candidates are listed in Tab. 1. The variable star name, the period from GCVS as well as the revised ACVS period (rounded to full days) and the difference in percent of the GCVS period are given. We also list the approximate time span elapsed between the observations leading to the GCVS period (typically the time of the first reported maximum) and the start of the ASAS monitoring. The candidates can be divided into two groups, one showing period changes of 10 to 20%, and one where the period is roughly halved or doubled. The latter group may indicate a change of the dominant pulsation mode in the past decades. Period changes in both directions are observed. The most promising candidates, based on the literature data, are marked with an asterisk in the table and are discussed in the following.

AX Mus: Swope (1931) analysed two long time series of observations of this star, separated by 4700^{d} and noted, that the best fit for the first dataset is 99^{d}, while the second dataset gives $97\overset{d}{.}3$. The ACVS value of 115^{d} may suggest a continuous period variation. Interestingly, the time of the first maximum in the ASAS light curve can be predicted to within 1 day accuracy using the $97\overset{d}{.}3$ period and a corresponding maximum (JD 2425330). Thus, $97\overset{d}{.}3$ seems to represent the average period of the light change of AX Mus pretty well.

V2121 Oph: This Mira has been studied by Clement et al. (1980) in the course of a search for variables in the globular cluster NGC 6284. It is likely a non-member. Clement et al. listed the individual photometric measurements they had used, so we could test the ACVS period of 296^{d}, which, however, gave a considerably worse fit than the value mentioned in that paper. The ratio between GCVS period and ACVS period is close to 2, therefore, we may witness a switch from first overtone to fundamental mode here.

WY Ser: The GCVS value is based on a study by Hoppe (1938). While the individual measurements are not given, Hoppe explicitly excluded the possibility of a halving of the period. On the other hand, there is no doubt from the ASAS data that WY Ser is currently pulsating with a period around 195^{d}.

V3190 Sgr: Payne (1928b) noted that earlier papers gave either $222\overset{d}{.}3$ or $227\overset{d}{.}3$ for this star, which interestingly would be very close to the ACVS value, but she found that 194^{d} clearly provided the best fit to the data analyzed by her.

V3343 Sgr: Plaut (1971) derived a period of this star of 134.2^{d} based on 18 measurements from four light cycles between JD 2435600 and JD 2436800. The ACVS period is $121\overset{d}{.}9$ which gives a very good fit of the ASAS data, but can be excluded for the Plaut data. On the other hand, the $134\overset{d}{.}2$ period is not representing the light change described by the ASAS data. The typical short time scatter in period length derived from the ASAS data is about 3%, i.e. clearly less than the difference observed. As a further check we divided the time difference between one maximum derived from the Plaut data and the first maximum of the ASAS data by the two period values. The Plaut value gives a ratio of 123.96, i.e. the maximum is deviating only 4% from the expected time, while the ACVS period is almost half a period off. We suggest that the rather small deviation found when using the Plaut period indicates that the star has changed its period to the current (ACVS) value quite recently.

BM Sgr: For this object another period determination besides the GCVS and ACVS value exists. Shawl & Bord (1990) give a period of 199 d, i.e. very close to the ACVS value, with a reference maximum at JD 2446501. The older period of 403^{d} from Payne (1928a) was based on 167 observations covering 35 epochs of the light change of BM Sgr. She noted that the "period is more than usually variable".

With the list of stars presented in Tab. 1 we would like to draw further attention to these objects as they seem to be good candidates for Miras with a previously unknown and probably evolutionary caused period change. This study is also a test case for a future comparison of data from forthcoming surveys with archive material.

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