Semiregular variables in the solar neighbourhood

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ABSTRACT

Period–luminosity sequences have been shown to exist among the semiregular variables (SRVs) in the Magellanic Clouds, the bulge of the Milky Way galaxy and elsewhere. Using modern-period and revised \textit{Hipparcos} parallax data, this paper demonstrates that they also appear among the M giant SRVs of the solar neighbourhood. Their distribution in the $K$, log $P$ diagram resembles that of Bulge stars more closely than those in the Magellanic Clouds. The prevalence of mass-loss among local M-type SRVs and its dependence on period and spectral subtype are also discussed. $K' - 2007$, a measure of circumstellar dust emission, increases clearly with $V$ amplitude, M giant subtype and log $P$.

Key words: stars: AGB and post-AGB -- stars: fundamental parameters -- stars: late-type -- stars: mass-loss -- stars: variables: other -- solar neighbourhood.

1 INTRODUCTION

The large-scale surveys for Massive Compact Halo Objects (MACHO), the Optical Gravitational Lensing Experiment (OGLE) and similar unbiased searches have revolutionized our knowledge of the variable star populations in the Galactic bulge and the Magellanic Clouds. Previous work relied on photographic surveys which usually revealed only objects having amplitudes of several tenths of a magnitude or more. Thus, while our knowledge of Miras was fairly complete in certain fields, this was not true of the SRVs, whose amplitudes are usually much smaller. Small-amplitude SRVs have turned out to be extremely numerous relative to large-amplitude ones, whenever searches have been sensitive enough to find them [e.g. see Wood et al. (1999) for the Large Magellanic Cloud (LMC) and Alard et al. (2001) for the Bulge].

Although the period–luminosity relation for Mira variables has been known for a long time, the analysis of MACHO data by Wood et al. (1999) showed that similar trends exist among the SRVs of the LMC. Wood (2000) found that there are at least five clear sequences (A, B, C, D and E) in the $K$, log $P$ diagram. More refined observations by Kiss & Bedding (2003) and Ita et al. (2004) have since made it clear that the A and B sequences undergo perceptible 'jogs' at about the level of the red giant branch (RGB) tip, requiring that they be subdivided into $A^+$, $A^-$, $B^+$ and $B^-$. In addition, they found a sequence designated by the latter as C' with the suggestion that it is populated by the first overtone Mira-like variables. The near-infrared (IR) yields tighter $M$, log $P$ relations than the visible region because of the diminished effect of interstellar reddening and the fact that the amplitude of variation is less.

Glass & Schultheis (2003) showed that SRV sequences are not confined to the Magellanic Clouds but also occur in the NGC 6522 Baade’s Window field in our own galaxy, though here they are smeared out due to the depth of the Bulge. Lebzelter et al. (2005) noted that a small number of nearby luminous SRVs with \textit{Hipparcos} parallaxes fall on the Wood B and the Wood C (Mira) sequences, as do several SRVs in the globular cluster (GC) 47 Tuc. Recently, the first results of a comprehensive survey of SRVs in GCs have been presented by Matsunaga et al. (2006). From their work, it is evident that the GC SRVs do not extend to such high luminosities as those in the Magellanic Clouds.

Whitelock (1986) found a relation between $M_{\text{bol}}$ and log $P$ for the SRVs in the GCs 47 Tuc and NGC 5927. Its slope agreed with the evolutionary tracks of Vassiliadis & Wood (1993). Similarly, in an analysis of the $M_K$, log $P$ diagram of nearby SRVs, Bedding & Zijlstra (1998) suggested that they fit a line parallel to Whitelock’s one but $\sim0.8$ mag brighter. The slope they found is much shallower than those of the $K$, log $P$ relations determined for LMC O-type Miras and for SRVs by Wood (2000). It may, however, represent an evolutionary track for the most luminous SRVs of the solar neighbourhood, though Glass & Schultheis (2003) suggested that it was probably an artefact arising from the poor knowledge of SRVs with small amplitudes then prevailing.

Population-dependent trends have been searched for by Schultheis, Glass & Cioni (2004) by analysing MACHO data from the two Magellanic Clouds and the NGC 6522 field in a similar manner. They found that as metallicity decreases the luminosity of the RGB tip decreases, the proportion of variable stars decreases and the minimum period associated with a given amplitude gets longer; that is, the amplitudes are lower when the metallicity is lower. The differences between the LMC and the Small Magellanic Cloud (SMC) have recently been investigated more thoroughly by Kiss & Lah (2006). Further, it is evident that there are few luminous stars on
the A+ and B+ sequences of the Milky Way field, in part due to the absence of carbon stars.

In this paper, the $M_K$, log $P$ diagram for nearby SRVs is re-examined in the light of new information that has become available. A small number of low-amplitude red variables have been discovered among the nearby stars and monitored photoelectrically over substantial time intervals, with the result that accurate periods have been determined for them. The Hipparcos parallax data have also been re-reduced using improved methods so that the probable errors in the distances of the red stars it observed are now approximately halved.

2 THE PRESENT SAMPLE

The sample of SRVs in this paper is drawn mainly from Percy, Wilson & Henry (2001c), Percy et al. (2001a), Percy, Nyssa & Henry (2001b) and Percy et al. (2004) in which periods and amplitudes are presented for a number of SRVs derived from long series of data taken by themselves and members of the American Association of Variable Star Observers. In addition, some stars listed by Bedding & Zijlstra (1998), Hron, Aringer & Kerschbaum (1997) and Olofsson et al. (2002) have been included (note: g Her = 30 Her) even though there may be no new information about their periods.

Table 2 shows the sample. As far as possible, it has been limited to M stars of luminosity class III (as listed by CDS, Strasbourg) and regarded as having SRa or SRb variability type. The individual stars in many cases have extensive literatures of their own. To be useful for the present purpose, each star must have a well-determined parallax, a $K$ magnitude and good period information. As a result of the first criterion, they will be nearby and therefore too bright to be present in the most recent near-IR sky surveys, the Deep Near Infrared Survey (DENIS) and the Two-Micron All-Sky Survey (2MASS).

The source of the period information is given in the ‘Reference’ column of the table. Inevitably for SRVs, the determination of characteristic periods is a lengthy affair, requiring observations stretching over many cycles (often also involving long secondary periods). There is room for argument about the correctness of the periods in many cases. The choice of periods to include in the analysis is explained in the footnotes of Table 2. This follows as far as possible the approach used in previous work by one of the authors and his collaborators concerning SRVs in the Magellanic Clouds and the NGC 6522 field, in the sense that only one each of the predominant short and long periods is retained.

The distances of these stars have been derived from the revised Hipparcos catalogue (van Leeuwen & Fantino 2005; van Leeuwen 2007). In this new version, the errors for red stars have usually been reduced by about a factor of 2 from the previously published catalogue (ESA 1997). Fig 1 shows the improvements due to the new parallax reductions (van Leeuwen & Fantino 2005; van Leeuwen 2007).

$K$-band magnitudes have been taken, in general, from the 2MASS survey of Neugebauer & Leighton (1969). Each source was observed a few times and the probable error of the magnitude was usually about 0.04 mag. Some additional magnitudes were supplied by Dr T. Lloyd Evans (University of St Andrews).

The amplitudes are from $V$ data, where available. Otherwise, $B$ or photographic ones have been used.

2.1 Biases in the sample

The sample cannot pretend to be complete. Only very few of the nearby late-type SRVs have been observed photometrically with the necessary precision and for sufficiently long times to determine their variability characteristics.

Since the sample is selected to some extent on parallax error, the Lutz–Kelker bias should be examined. The calculations of Koen (1992, case $p = 2$) may be used to determine the mean value of $\Delta M$, the error in the estimate of the distance modulus. The mean value of $\sigma_\pi/\pi$ for the $\pi > 3\sigma_\pi$ sample (see below) is $\sim 0.1$; according to Koen (Table 2), 0.07 mag is the average amount by which stars will have been shifted downwards in Fig. 1. The mean for the $\pi > 10\sigma_\pi$ sample is $\sim 0.063$; the average downward shift in Fig. 2 is then about 0.025 mag.

Glass & Schultheis (2002), using observations made during the MACHO gravitational lensing project, showed that essentially all...
M giants giants present in the Bright Star Catalogue (Hoffleit & Warren 1991) and the numbers of these present in Table 2. (Intermediate subtypes such as M5.5III were not considered.)

In making comparisons with the Magellanic Cloud and NGC 6522 results, it must be remembered that the IRC $K$ magnitudes use the traditional broad-band $K$ and not the $K_2$ band of DENIS and 2MASS. The latter filter does not include the CO first overtone band which is prominent in late-type stars. The absence of the 2.3-$\mu$m absorption it causes may make the local sample appear a few hundredths of a mag fainter than if $K_2$ were used.

Further, no compensation has been applied for interstellar reddening to the local $K$ values. It is estimated that this will not be more than one or two hundredths of a magnitude in most cases.

### 3 THE $M_K$, log $P$ DIAGRAM

The $M_K$, log $P$ diagram can be presented in several different ways. Fig. 2 shows $M_K$ versus log $P$ for all the sources in the sample with significant parallaxes ($\pi > 3\sigma_\pi$). The expected positions of the various series as defined by Ita et al. (2004) for the LMC are shown as dotted parallelogram boxes, assuming a distance modulus of 18.5. The error bars are based on the quoted probable errors in the parallax. Some of these are quite large, leading to ambiguity as to which box a particular point belongs to.

### Table 1. M giants in the Bright Star Catalogue and number of these in the present sample.

| Subtype$^a$ | No. in BSC | of which, no. in Table 2 |
|------------|------------|--------------------------|
| M0         | 64         | 2                        |
| M1         | 80         | 0                        |
| M2         | 73         | 2                        |
| M3         | 52         | 6                        |
| M4         | 44         | 5                        |
| M5         | 17         | 4                        |
| M6         | 7          | 4$^b$                     |
| M7         | 0          | 0                        |

$^a$Note. subclass M0 includes M0III, M0IIa, M0IIb and M0IIIab.

$^b$g Her is given as M6-III in the BSC.

### Table 2. Data for local M-type SRVs in sample.

| HD       | Name     | Sp     | Periods (d) | $\pi$   | $\sigma_\pi$ | $K$  | Amplitude | Reference |
|----------|----------|--------|-------------|---------|--------------|-----|-----------|-----------|
| 002411   | TV Psc   | M3III  | 55$^*$      | 6.16    | 0.59         | −0.16 | 0.5       | PWH       |
| 003346   | V428 And | M6III  | 11, 11.5, 15.22 | 5.28   | 0.30         | 1.20 | 0.065     | PNH       |
| 004174   | EG And   | M2e sym | 29.1$^e$, 47.6 | 1.96   | 0.64         | 2.74 | 0.27      | P et al.  |
| 004408   | NSV 00293 | M4III | 12?, 32?, 40? | 4.20   | 0.29         | 0.15 | 0.22      | PDKT      |
| 005820   | WW Psc   | M2III  | 25, 300     | 3.03    | 0.42         | 1.58 | 0.23      | PDKT      |
| 013596   | CSV 100168 | M0III | 32, 275;     | 6.81    | 0.38         | 1.80 | 0.14      | PKDT      |
| 017491   | Z Eri    | M5III  | 80          | 3.87    | 0.49         | 0.32 | 1.63      | GCVS      |
| 018191   | RZ Ari   | M6III  | 37.7, 56.5$^a$ | 9.28   | 0.30         | −1.08 | 0.4       | P et al.  |
| 022689   | SS Cep   | M5III  | 90          | 3.84    | 0.49         | −0.56 | 1.1       | GCVS      |
| 029712   | R Dor    | M8IIe  | 300         | 18.35   | 1.01         | −3.91 | 1.8       | GCVS      |
| 030959   | 4 Ori    | M3 (S) | 36$, 52.6, 74.1 | 5.02   | 0.72         | −0.53 | 0.3       | P et al.  |
| 033664   | RX Lep   | M6III  | 60/80,long  | 6.70    | 0.43         | −1.25 | 0.5       | GCVS/PWH  |
| 039983   | BO Ori   | M5III  | 110        | 4.74    | 1.22         | 0.84 | 2.1       | GCVS      |
| 041698   | S Lep    | M5III  | 89          | 4.90    | 0.63         | −0.49 | 1.58      | GCVS      |
| 042973   | UW Lyn   | M3III  | 26, 37.6$^e$, 49.5$^a$ | 5.12   | 0.33         | 0.73 | 0.15      | P et al.  |
| 042995   | $\eta$ Gem | M3III | 234$, shorter? | 8.52   | 1.22         | −1.49 | 0.3       | PWH       |
| 044478   | $\mu$ Gem | M3III | 20, 27.0$, 51.0$ | 14.10  | 0.71         | −1.89 | 0.23      | P et al.  |
| 051725   | VS23 Mon | M5     | 26, 34.1$, 45.6$ | 2.83   | 0.63         | 1.34 | 0.2       | P et al.  |
| 056096   | L2 Pup   | M5IIe  | 140.6       | 15.61   | 0.99         | −2.15 | 1.2       | BZ        |
| 062647   | NSV 03721 | M3III | 22$, 360$ | 7.51    | 0.41         | 0.89 | 0.13      | PDKT      |
| 064052   | BC CMi   | M4III  | 20$, 28$, 45$ | 6.44   | 0.47         | 0.86 | 0.5       | P et al.  |
| 073844   | AK Hya   | M6III  | 50$^e$      | 6.37    | 0.42         | −0.57 | 1.16      | PDKT      |
| 075716   | BO Cnc   | M3III  | 27, 270$^b$ | 3.70    | 0.75         | 1.39 | 0.26      | PDKT      |
| 077443   | UX Lyn   | M3     | 37.2$, 51.3$ | 4.16    | 0.63         | 0.48 | 0.8       | P et al.  |
| 094705   | VY Leo   | M5III  | 48, 500     | 8.42    | 0.37         | −0.80 | 0.75      | PDKT      |
| 099592   | ST Uma   | M4/5III | 50, 81$, 625$ | 1.38   | 0.43         | 0.58 | 0.7       | PWH       |
| 101153   | $\alpha$ Vir | M4III | 30, 275 | 6.57    | 0.36         | −0.27 | 0.28      | PDKT      |
| 102159   | TV Uma   | M4III  | 600         | 4.34    | 0.81         | 0.83 | 0.72      | PDKT      |
| 112264   | TU CVn   | M5III  | 44.5$, 230$ | 4.69    | 0.32         | −0.13 | 0.35      | PWH       |
| 113825   | RT Vir   | M8III  | 155         | 7.46    | 0.86         | −0.97 | 1.29      | GCVS      |
| 113866   | FS Com   | M5III  | 38.2, 55.4$^e$ | 4.43   | 0.41         | −0.21 | 0.35      | P et al.  |
| 114961   | SW Vir   | M7III  | 155         | 7.01    | 0.84         | −1.74 | 1.85/1.8  | PDKT/PWH  |
| 115322   | FH Vir   | M6III  | 72, 280     | 1.33    | 0.69         | 1.45 | 1.19      | PDKT      |
| 118767   | V744 Cen | M5III  | 90          | 6.35    | 0.33         | −0.75 | 1.41      | GCVS      |
| 120285   | W Hya    | M7e    | 361         | 9.77    | 1.17         | −3.17 | 3.1       | GCVS      |
| 122250   | $\theta$ Aps | M6.5III | 119 | 8.84    | 0.49         | −1.92 | 2.2       | GCVS      |
Table 2 – continued

| HD     | Name   | Sp  | Periods (d) | π    | σπ   | K     | Amplitude | Reference |
|--------|--------|-----|-------------|------|-----|-------|-----------|-----------|
| 124304 | EV Vir | M3III | 19, 57      | 1.98 | 0.58 | 1.52  | 0.52      | PDKT     |
| 124681 | FS Vir | M4III | 20, 250     | 4.04 | 0.52 | 1.54  | 0.18      | PDKT     |
| 125180 | CY Boo | M3III | 23, 350     | 4.28 | 0.41 | 1.49  | 0.10      | PDKT     |
| 126327 | RX Boo | M7.5  | 340         | 4.98 | 0.64 | −1.85 | 2.7       | GCVS     |
| 140297 | RR CrB | M3    | 60.8        | 2.93 | 0.53 | 0.94  | 1.7       | GCVS     |
| 143347 | RS CrB | M7    | 333         | 3.05 | 0.40 | 1.77  | 2.9       | GCVS     |
| 144205 | X Her  | M8    | 95.0        | 7.31 | 0.40 | −1.48 | 0.6       | GCVS     |
| 148783 | g Her  | M6III | 93*, 833*   | 9.22 | 0.18 | −1.99 | 0.6       | GCVS     |
| 150077 | TX Dra | M5    | 78          | 2.91 | 0.53 | 1.43  | 2.3       | GCVS     |
| 151187 | S Dra  | M6III | 136         | 2.42 | 0.77 | 0.06  | 1.0       | GCVS     |
| 151522 | AH Dra | M5    | 158         | 2.56 | 0.72 | 0.59  | 0.8       | GCVS     |
| 159354 | V642 Her| M4III | 25.6, 35.7a | 5.41 | 0.52 | 0.93  | 0.29      | P et al. |
| 167006 | V669 Her| M3III | 5.99        | 5.99 | 0.22 | 0.35  | 0.17      | JDKT     |
| 175865 | R Lyr  | M5III | 45.9, 64.1a | 10.96| 0.12 | −2.10 | 0.6       | P et al. |
| 184008 | AF Cyg | M5    | 92.5        | 4.53 | 0.64 | 0.29  | 2.0       | GCVS     |
| 184313 | V450 Aql| M5/5.5III| 65*      | 4.94 | 0.47 | 0.14  | 0.35      | PWH      |
| 186776 | V973 Cyg| M3III | 35, 376     | 3.98 | 0.39 | 1.49  | 0.40      | JDKT     |
| 190298 | M0III  | 12, 13, 40|         | 2.80 | 0.56 | 1.06  | 0.041     | PNH      |
| 203712 | V1070 Cyg| M7III | 110, 470/60, 50±, complex | 6.21 | 0.44 | −0.66 | 0.83      | PDKT/PWH |
| 205730 | W Cyg  | M4III | 130.4*, complex/131.1 | 5.70 | 0.38 | −1.35 | 1.0       | PWH/GCVS |
| 207076 | EP Aqr  | M6IIIv | 55         | 8.82 | 0.63 | −1.55 | 0.45      | GCVS     |
| 209958 | TW Peg  | M7.5IIIv | 929      | 7.50 | 0.89 | −0.63 | 0.9       | GCVS     |
| 215162 | BD Peg  | M8    | 78         | 4.29 | 1.11 | 1.10  | 0.9       | GCVS     |

Notes. V amplitudes are usually given; in a few cases only B or photographic is available.

CSV: Combined General Catalogue of Variable Stars (Samus et al. 2004).
P et al.: Percy et al. (2004); \(^\text{a}\) denotes first rank. Amplitudes of stars with P et al. in the reference column are in fact taken from PWH.
PDKT: Percy et al. (2001a). More certain periods given in bold-face type; less certain periods denoted by a colon.
PNH: Percy et al. (2001b). Most secure periods given in bold-face type; most uncertain periods are marked with a colon.
PWH: Percy et al. (2001c). The periods marked with an asterisk are the ones which seem to be most stable and well determined. The amplitude of V450 Aql is taken from GCVS.

For L2 Pup an average V amplitude is given (Fig. 1; Bedding et al. 2002). Its K mag was taken to be \(-2.15\) (Bedding et al. 2002, footnote, p. 81).

It can be seen that there are a few apparent exceptions to the Ita et al. classifications, such as the occurrence of single-period variables in or near the D box and large-amplitude variables in the B+ box. Some of these may simply be attributed to limited or poor data. Other effects are discussed below in connection with Fig. 4.

A more refined diagram is given in Fig. 3, where only sources with parallaxes greater than 10 times their probable error are shown. The error bars are sufficiently small that most of the stars can be assigned to the appropriate Ita et al. (2004) boxes with confidence.

A general view of the \(M_K\), log \(P\) diagram for fields of different metallicity is given in Fig. 4. The data for the LMC, the SMC and the NGC 6522 Baade’s Window field of the Galactic bulge are taken from fig. 5 of Schultheis et al. (2004). The photometry of these fields is from 2MASS and the periods are from MACHO, and have been derived in the same way. Only the predominant periods have been included except that in those cases with a long secondary period, both have been plotted. Some stars fall above the Ita et al. boxes because the latter’s data were taken with the Simultaneous 3-colour Infra Red Imager for Unbiased Surveys (SIRIUS) camera on the Infrared Survey Facility (IRSF) telescope at Sutherland and show saturation at fainter limits. The levels of the tips of the RGBs have been taken to be \(M_{K,0} = -6.48\) in the LMC.
Figure 4. Comparison of the \( K, \log P \) diagrams for SRVs in the two Magellanic Clouds, the NGC 6522 field in the Bulge and the solar neighbourhood. The ‘Local’ box is the same as in Fig. 2 except that the error bars have been omitted (see Fig. 1 for additional information). Note that (a) the distance moduli of the LMC, the SMC and the NGC 6522 fields have been taken to be 18.5, 18.94 and 14.7, respectively; (b) the non-local \( K \)-band data have been taken from the 2MASS survey; (c) the scatter in the Bulge is intrinsically higher than in the other fields because of depth effects; (d) the levels of the RGBs, indicated by dotted horizontal lines, are as given in the text and (e) Mira variables have not, in general, been included in the local sample.

and \(-6.26\) in the SMC, based on the values given by Kiss & Bedding (2004). For the RGB tip in the NGC 6522 field, the difference of 0.3 mag in level from that of the LMC, determined by Schultheis et al. (2004), has simply been subtracted (to get \(-6.78\)).

The amplitude criterion for large-amplitude variables applied in the LMC, the SMC and the NGC 6522 fields is \( \Delta V_{\text{MACHO}} > 1.0 \), whereas that for the local sample is \( \Delta V > 1.0 \). Since the \( V \) amplitudes are usually somewhat greater than those at \( r_{\text{MACHO}} \), it is probable that more local stars have been classified as having large amplitudes than should have been. If \( \Delta V > 1.63 \) is adopted as the criterion, the only large-amplitude stars are those in or close to box C.

There are several clear trends between the first three samples. The A, B and upper C sequences are relatively more populated in the Magellanic Clouds than in the Bulge. The low ends of the C (Mira) and C′ sequences are relatively underpopulated in the Magellanic Clouds. Doubly periodic variables are sparse or lacking at the lower luminosity end in the Magellanic Clouds. Further, the number of small-amplitude variables in the C box declines with increasing metallicity (SMC \( \rightarrow \) LMC \( \rightarrow \) NGC 6522).

As mentioned, Matsunaga et al. (2006) have presented a preliminary \( K, \log P \) diagram (their fig. 1) for galactic GCs. This may be compared to Fig. 4. No members of the A sequence have yet been found among the GCs, though this may be a consequence of their smaller amplitude and the fact that the survey was carried out in \( JHK' \). The B′ and C′ sequences in the GCs cut-off at \( M_K \sim -6.5 \) and \(-6.3\), respectively, which is about the level of the RGB tip. The corresponding level for the NGC 6522 field is about \(-7.5\). Even the C sequence Miras, which are confined to the metal-rich clusters, reach no further than \( M_K \sim -7.6 \) in the GCs, as compared to \(-8.8\) in the Bulge. Matsunaga et al. attribute the effects they discuss to differences in the initial mass functions between the two fields (lower masses in the GCs).

In comparing the local M-type SRVs with the others, we must remember that normal Miras have been omitted and that the relative lack of short-period and small-amplitude SRVs is largely a selection effect. Further, the most luminous Magellanic Cloud SRVs are carbon stars, which are not present in the Bulge and have not been included in the local sample.

The more luminous part of the local M-star sample should be directly comparable to the Bulge field, where there are no C stars. The A, B and C′ sequences seem to cut-off at the same levels, both of which are well below the luminosities reached in the Magellanic Clouds. This is also true of the D sequence, though the latter is not a truly independent one, being composed of stars that have simultaneous shorter periods in the B and C′ sequences. The lower luminosity ends of the C and D sequences can also be compared, since these stars have moderately large amplitudes and hence are easier to detect as variables. Again, though the significance of the conclusion is limited by the small numbers, the parameter space occupied by the members of each field is similar.

The conclusion seems to be that the local M giant SRVs compare most closely with those in the NGC 6522 field.

4 PREVALENCE OF MASS LOSS

Early results from the ISOGAL survey at 7 and 15 µm using the ISOCAM camera of the Infrared Space Observatory (ISO) satellite showed from the [15], [7]−[15] diagrams that there is a sequence of increasing mass loss from early- to late-type M stars on the
asymptotic giant branch (AGB) in the Bulge (Glass et al. 1999; Omont et al. 1999). It is not confined to the known Mira variables; substantial mass loss also occurs in other late-type M giants (see Glass & Schultheis (2002) for an analysis of the complete sample of M giants observed by Blanco (1986) in the NGC 6522 Baade’s Window clear field towards the Galactic bulge).

The presence of mass loss from the present sample of SRVs is seen from their $K - [12]$ colours. The $K$ band is contributed mainly by the stellar photospheres of these stars but the [12] band, as the ISO 15 μm band, can be heavily affected by radiation from dust in circumstellar shells. The [12] mag for almost all the stars in Table 2 are available from the IRAS point source catalogue (Beichman et al. 1988). Miras have much smaller amplitudes in the IR than in the visible and, by analogy, the amplitudes of SRVs in the IR are expected to be modest, of the order of a few tenths of a mag at maximum. For example, the short-term variability of L2 Pup at $K$ is about a quarter of that at $V$ (Bedding et al. 2002). Nevertheless, some degree of uncertainty in their $K - [12]$ colours must be expected from variability. The calibration of the relation between $\dot{M}$ ($M_\odot$ yr$^{-1}$) and $K - [12]$ has been discussed by Whitelock et al. (1994); saturation is reached at $K - [12]$, $\sim 5$, corresponding to a mass-loss rate of about log $\dot{M} \sim -5$. The dust mass-loss rates from SRVs in the LMC, the SMC and the NGC 6522 fields appear to be fairly similar from ISO data (Schultheis et al. 2004, fig. 16).

Fig. 5 shows that IR excesses are associated with large amplitude of variation. The minimum of $K - [12]$ colour for the sample is offset by about 0.5 mag, which is appropriate for early M-type giant photospheres. It is based on a 12 μm mag of 0 corresponding to 28.3 Jy (Beichman et al. 1988).

The $K - [12]$ colour is also shown as a function of M giant subtype in Fig. 6. Colour excesses begin to appear at M3, as also found by Glass & Schultheis (2002) in an analysis of a complete sample of M giants observed by Blanco (1986) in the NGC 6522 Baade’s Window clear field towards the Galactic bulge.

Fig. 7 shows the $K - [12]$ colour versus log (period) for the sample. There is a very clear increase of IR excess with period, starting at about log $P = 1.75$ ($P = 56$ d). This is in agreement with the results of Alard et al. (2001) for the NGC 6522 Baade’s Window variables as well as the LMC and the SMC fields of Schultheis et al. (2004).

Of the 64 variables listed in Table 2, 35 have had their IRAS (10 μm region) spectra classified by Sloan & Price (1998). 10 of them show ‘naked’ photospheres; that is, dust shells were not detected. They correspond to the shortest-period SRVs. The remainder are classified as types SE1 to SE8, according to the strength of their SiO features. Many are also classified as ‘t’, meaning that they show the 13 μm feature. The SE subclasses and presence or absence of the ‘t’ show no correlation with $K - [12]$ colour.

Given the fairly clear dependence of $K - [12]$ colour on M giant subtype and log $P$ seen in Figs 6 and 7, it is surprising that Olofsson et al. (2002), using mass-loss rates for SRVs based on CO radio data, do not see clear correlations with pulsation period or stellar blackbody temperature (their figs 7 and 8).

5 PROSPECTS FOR PROGRESS

The current picture of SRVs in the solar neighbourhood, though improved in detail, remains sketchy because of the small size and
haphazard nature of the sample. Enough evidence now exists, however, to show that local SRVs occupy the same areas of the $K$, log $P$ diagram as stars in the NGC 6522 field of the Bulge and that they obey similar $K$–log $P$ relations.

The currently available data, especially at the short-period end, are too sparse. \textit{Hipparcos} parallaxes are available for numerous early M-type stars which have not yet been monitored with sufficient accuracy or for long enough times to find their variability properties. While these stars are usually too bright to be included in current all-sky monitoring projects, they are suitable for photometric measurements with small telescopes. Thus, frequent measurements over periods of 1 year or more, though tedious, can certainly be contemplated.

Because the \textit{Hipparcos} parallaxes are directly the result of trigonometrical determinations and often of high accuracy, an increase of the number in the sample will yield a sounder absolute calibration of the properties of the SRVs and other M-type giants. With a better understanding of the effects of metallicity and age, they may even prove useful as distance indicators.

Finally, we note that $K$-band observations for bright stars are fortunately still possible.

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