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Long-term $UBV(RI)_\mathrm{c}$ monitoring of 12 southern hemisphere Long Period Variables[⋆]

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Abstract. A program of $UBV(RI)_\mathrm{c}$ photometric observations of twelve southern hemisphere Long Period Variables (LPV or Miras) has been carried out at the European Southern Observatory. Each star was observed on at least 11 occasions up to 29 over a 4-year period. A determination of their spectral types from the $(V{-}R_\mathrm{c})$ and $(R_\mathrm{c}{-}I_\mathrm{c})$ colours was also performed using the method described by Celis (1986b). We therefore present for the first time spectral type variations together with visible and colour light-curves for at least three successive cycles. New photometric parameters as visible and spectral type extrema are given. Spectral type variations are found in the range $1.3-4.5$ subclasses. The variations during a cycle and from cycle-to-cycle are discussed and short-term declines with large amplitude are reported for R Oct and RY Hyi. We finally estimate the distance of these stars using a (M_V^max, P, Spectral type) relation. It is shown that rather good distances (mean error less than 30%) can be determined if the period of the stars is known and good $UBVRI$ data are collected at the maximum of luminosity.[1]

Key words: stars: late-type — stars: AGB and post-AGB — stars: variables — stars: distances

1. Introduction

This paper reports on nearly 1 200 photometric observations of twelve oxygen-rich Long Period Variables (LPV) through the five filters of the $UBV(RI)_\mathrm{c}$ system. All these pulsating variables are classified as Miras ($P \gtrsim 100$ days and $\Delta V \geq 2.5$ mag following the definition proposed by Kholopov et al. 1985). Due to their long-term variations, the study of Miras requires a large amount of observations collected at different epochs and for several years. Photometry is a useful and easy tool to get such data. Most of the previous programs have studied the Mira visible and colour light-curves with UBV photometry only (see Celis 1986a or 1995 and references therein). On the other hand, as soon as it was possible to collect near-infrared photometric data, cool red giants became among the most interesting targets. Luminosity variations were studied, spectral types - infrared colour indices and colour or period-luminosity relations were also derived (see Eggen 1975b or Celis 1995). Nevertheless very few complete $UBVRI$ light-curves of Miras have been published up to now. Most of the observations were indeed collected for quite a short term. Only Eggen (1975a) reported $UBVRI$ observations for ten LPV similar to the ones that are presented in the present paper. He monitored these Miras during five years and discussed the data in Eggen (1975b). He pointed out among others that large variations of magnitudes and colours occur between different cycles especially near the maximum of luminosity. This confirmed previous results obtained from UBV studies claiming that the repeatability of the light variations in different cycles is poor. Reconstruction of light-curves from observations collected during different cycles should thus be avoided and consecutive observations may instead be used to study LPV variations. Finally infrared light-curves of Miras (where these stars radiate most of their energy) have been published more recently by Le Bertre (1988, 1992 and 1993) and by Feast and collaborators (see for instance Whitelock et al. 1991 and references therein).

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[⋆] Based on observations carried out at the European Southern Observatory, Chile.

[1] Table 2 is available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

Table 1. List of observed Miras. N_{obs} is the number of observations collected for each star (see text for a complete description of the table). The star properties are taken fromKholopov et al. (1985) except (^{a}) fromCrowe & Garrisson (1988), (^{b}) fromCelis (1986a), (^{c}) fromJura & Kleinmann (1992) and (^{d}) fromCelis (1984)

Name	α (2 000.0)			δ (2 000.0)			Period	V_{max}	/	V_{min}	Spectral Type	LRS	N_{obs}
	(h)	(m)	(s)	(°)	(′)	(″)	(days)						
R Cha	08	21	48.	−76	21	18	334.6	7.5	/	14.2	M4-M7(M8^{a,b})	31	22
V Cha	07	46	36.	−78	01	18		12.0	/	>14.	M5	14	18
W Cha	08	28	22.8	−76	33	42	286.3	12.0	/	16.0			16
W Hyi	00	32	40.6	−79	40	20	281	13.0	/	>16.	M		18
X Hyi	00	39	39.	−80	01	42	308.5	12.8	/	16.0	M^c	23	21
RY Hyi	01	33	42.	−75	12	36	319	11.0	/	15.5	M5	15	29
R Oct	05	26	07.1	−86	23	18	405.5	6.4	/	13.2	M5.5-(M7^d)	15	28
T Oct	21	13	58.	−82	06	12	218.5	8.8	/	14.8	M2-M4(M6^a)		23
V Oct	22	07	59.	−74	46	48	289.5	11.6	/	>13.	M6-M7		11
RT Oct	23	00	35.	−87	02	30	180.2	10.4	/	14.6	M		19
RU Oct	00	08	47.	−86	10	12	373	10.2	/	15.0	M^c	14	26
U Tuc	00	57	13.2	−74	59	58	264.8	8.0	/	14.8	M3-M7		21

The number of collected $UBVRI$ light-curves of LPV is thus quite small up to now. This is certainly due to the difficulty to monitor these stars for several years: the periods are long, the minima are often very faint and a large amount of telescope time is needed. Furthermore this class of stars is actually not homogeneous and the rather small sample of Eggen has thus to be increased. More recent studies have also shown that several characteristics (spectral type, distance) of these stars can be deduced from their $UBVRI$ photometry (see Celis 1995). Let us finally point out that such data are strongly needed to constrain model atmospheres. The aim of this monitoring program of LPV was thus to collect a large amount of homogeneous $UBV(RI)_c$ photometric data covering several successive cycles. We planned to study (i) the simultaneous variations of the light-curves in the visible and near-infrared filters together with spectral type changes for a complete cycle, and (ii) the differences from cycle-to-cycle. This paper is organized as follows. In the next section, the selection criteria of the targets, the observations and their reduction are presented. The final data and the derived spectral types at all phases are given together with the visible and colour light-curves. We then discuss in Sect. 3 the main properties of the light-curves and spectral type variations. We also determine there the distance of these Miras and estimate the precision of the method used. The paper is finally summarized in Sect. 4.

2. Observations and results

We selected twelve Miras with bright minima found close to the celestial south pole in order to be able to observe them over the whole year. For homogeneity reasons all the LPV in our sample are oxygen-rich Miras. Since the spectral type of W Cha was not known before this work we first observed it with a Boller & Chivens spectrograph at the ESO 1.52-m telescope equipped with a CCD detector. A spectrum (shown in Fig. 1) was collected in the $5400 - 6000$ Å wavelength region with a dispersion of 32 Å/mm. The absence of any bands of the C_2 and CN molecules and the detection of strong absorption bands of TiO confirm that W Cha actually is an oxygen-rich star. Furthermore the strongest band of the ZrO β system (5551.7 Å) being absent, W Cha is not a S-type star and actually a M-type one.

The selected Miras have a period in the range of $180 - 400$ days which allowed us to observe them for at least three consecutive cycles over a 4-year period. We can guess that the properties of these stars are rather different. Indeed Feast (1963) showed that Miras with different periods exhibit distinctive kinematic properties. This was confirmed by Foy et al. (1975). A break in the properties of LPV (metallicities, initial masses, etc.) is also suspected around $P \simeq 300$ days (Little et al. 1987 and Jura & Kleinmann 1992).

On the other hand none of these Miras have been observed in OH-maser lines except R Oct with no detection (Le Squeren 1996). We have found that six stars in our sample have been classified from their IRAS Low Resolution Spectrum. All of them have a period larger

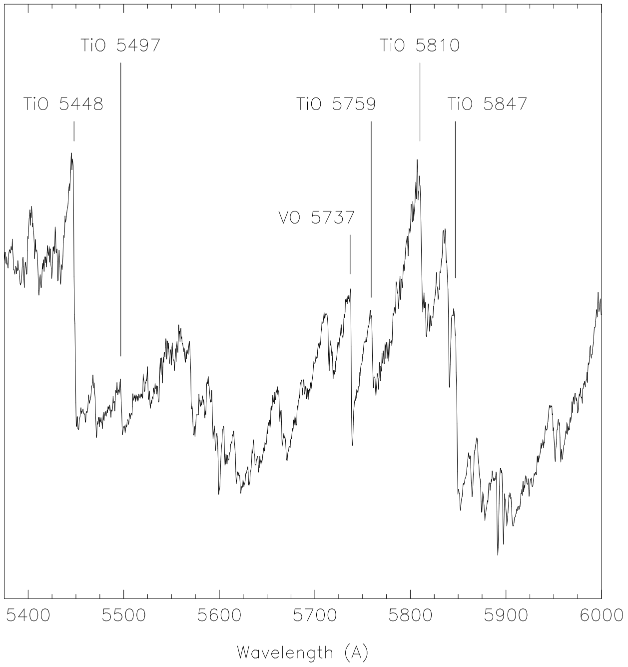


Fig. 1. The spectrum of the oxygen-rich Mira W Cha

than 300 days (confirming Feast 1986, who pointed out that Miras with a smaller period were not detected by IRAS). They have been classified as oxygen-rich sources with blue continuous energy distribution. The infrared spectra of V Cha, RY Hyi, R Oct and RU Oct are quite similar between 8 and 13 μm: they exhibit no emission or absorption features. X Hyi is a star showing a 10 μm silicate band emission and R Cha a silicate absorption. These two stars thus differ by the optical thickness of their oxygen-rich envelope, R Cha having the thickest one. Finally R Oct is a "o2" star in the Valinhos classification (Fouqué et al. 1992).

The main characteristics of the selected stars found in the literature are listed in Table 1. We give there the mean period of their light-curve in the visible, the V magnitudes of the brightest maximum and the faintest minimum ever observed, their spectral type at the extrema, the IRAS LRS spectral classification and finally the number of observations we made.

The observations were collected at the European Southern Observatory (La Silla, Chile) from September 1991 to January 1995. We used the ESO 50-cm Cassegrain telescope equiped with the single channel photometer and the thermoelectrically cooled Hamamatsu R943-02 photomultiplier tube. This photomultiplier was chosen because of its almost constant sensitivity over the whole spectral domain studied (see for instance Fig. 4.2 of Schwarz & Melnick 1993). We used standard $UBV(RI)_c$ ESO filters. A neutral density was placed in front of the I_c filter to avoid to saturate the photomultiplier for the brightest stars. Transformation coefficients were obtained by observing Cousins's E and F-region photometric standard stars chosen from the list given by Menzies et al. (1989). All the observations were reduced with the ESO photometric reduction program SNOPY. Given the precision of the standards data and extinction and transformation errors we have rejected each measurement with an error larger than 0.1 mag. Finally the published data have a mean accuracy better than 0.05 mag in the five colours.

The journal of the observations and all the $UBV(RI)_c$ data are compiled in Table 2. It was not possible to get a sampling of the light-curves as good as desired. The distribution of allocated nights, those lost due to bad weather conditions, and first of all the technical problems with the ESO 50-cm telescope are responsible for the periods without any measurements, some of them as long as a few months.

We also report in Table 2 the derived spectral types of the Miras in the observed phases of the light-curve. The M-spectral subtypes are defined from the intensity of the molecular absorptions of the TiO and VO molecules. Celis (1986a, 1986b and references therein) showed that these subtypes can be obtained from the $(V-R_c)$ and (R_c-I_c) colour indices. This is confirmed by model atmospheres of cool giant stars and particularly the estimation of the effective temperature from the (R_c-I_c) colour index (Plez et al. 1992). Furthermore since our phase coverage is quite good the use of colours to derive probable spectral types is worthwhile. On a practical point of view Celis (1986b, Fig. 1) showed that the distribution of the M Miras conforms to a sequence in a $(V-R_c, R_c-I_c)$ colours diagram. He then derived two spectral types-colour index scales. The derived spectral types reported in Table 2 are the mean of the ones that have been calculated from these two relations. They are consistent with the previous determinations reported in Table 1 and discussed in Sect. 3.3.

The obtained visible and colour light-curves are plotted in Fig. 2. A period search was performed for V Cha since it was not known. We found 400 ± 10 days over the three observed cycles. The evaluation of the period of the other stars is consistent with the previous determinations reported in Table 1. We have thus reconstructed the cycles by assuming that the periods have not changed since 1985 and are constant over the 4-year period of the observations. The data belonging to different cycles are plotted using different symbols in order to illustrate the cycle-to-cycle variations. The maximum of each cycle ($\phi = 0$) corresponds to the largest V magnitude we observed. Since the sampling of the light-curves is actually not regular there might be some small discrepancies between the maximum of the plotted light-curves and the real maximum of luminosity of the stars that was perhaps not observed. Finally the observations cover between three and seven successive cycles.

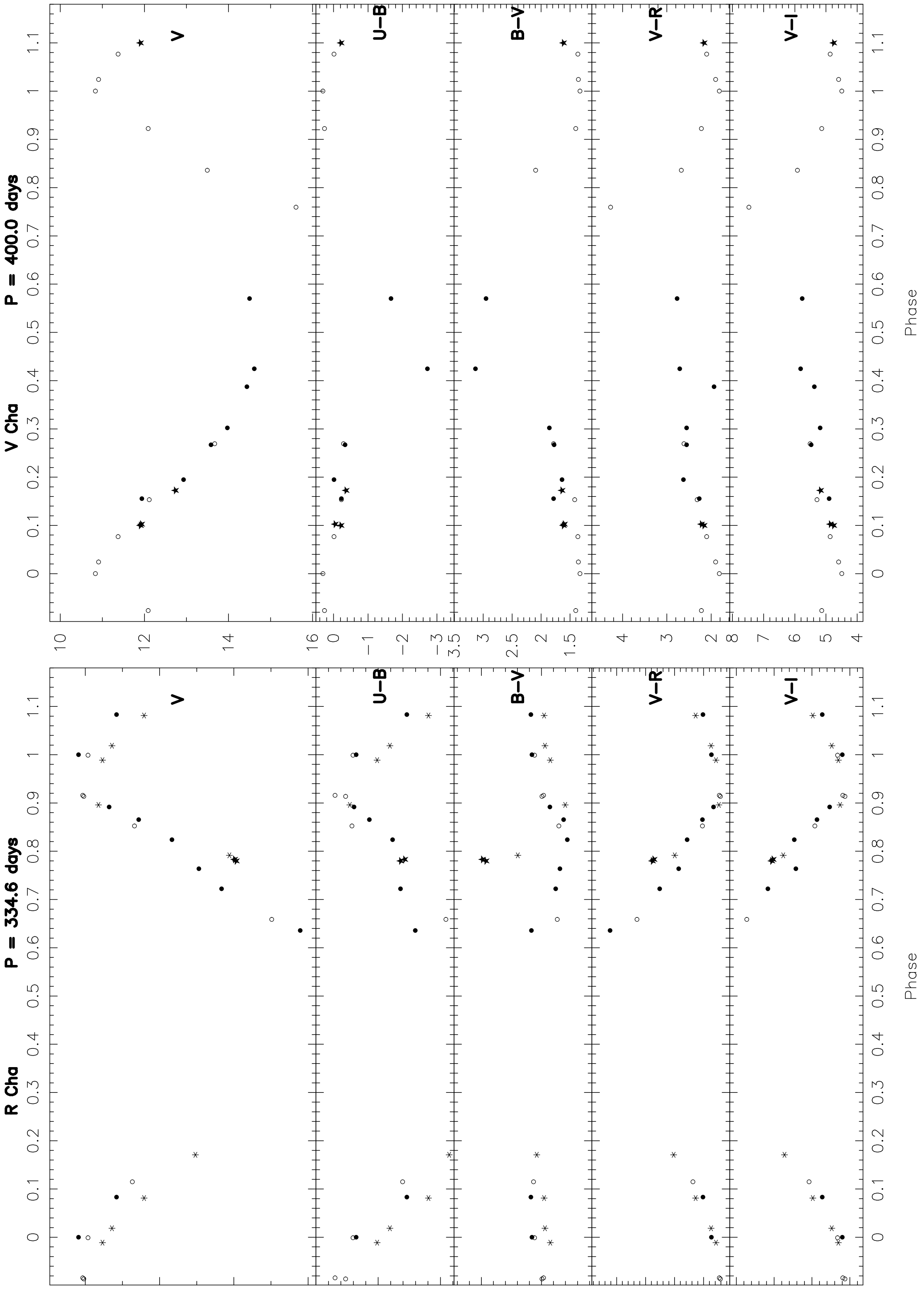
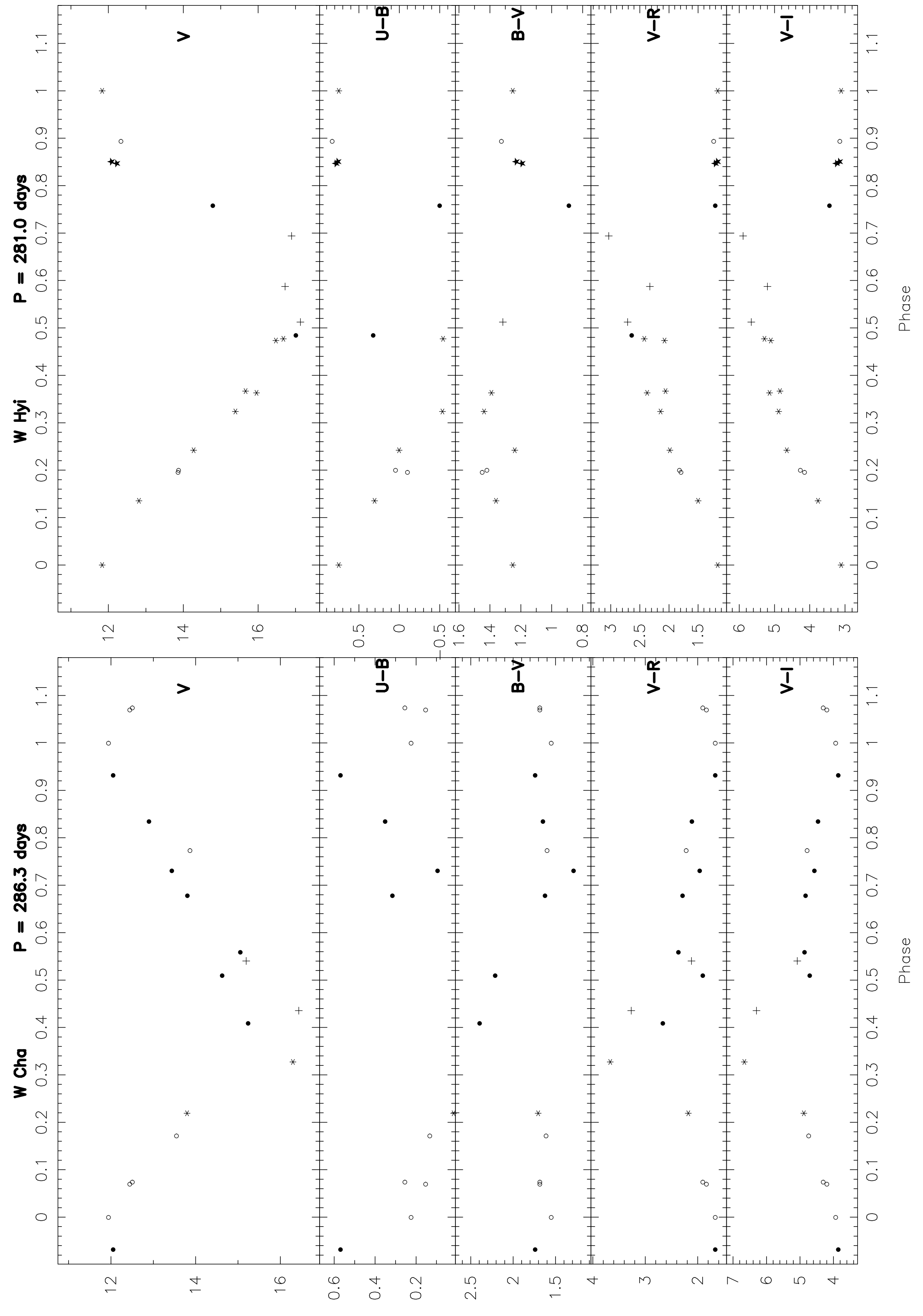


Fig. 2. The observed visible and colour light-curves of the twelve Miras. The different symbols correspond to the successive cycles n that we observed. First cycle (observations in late 1991): filled circle (•); $n = 2$ (one period later): filled star (⋆); $n = 3$: open circle (○); $n = 4$: asterisk (∗); $n = 5$: plus (+); $n = 6$: open rhombus (◇) and $n = 7$: open square (□)



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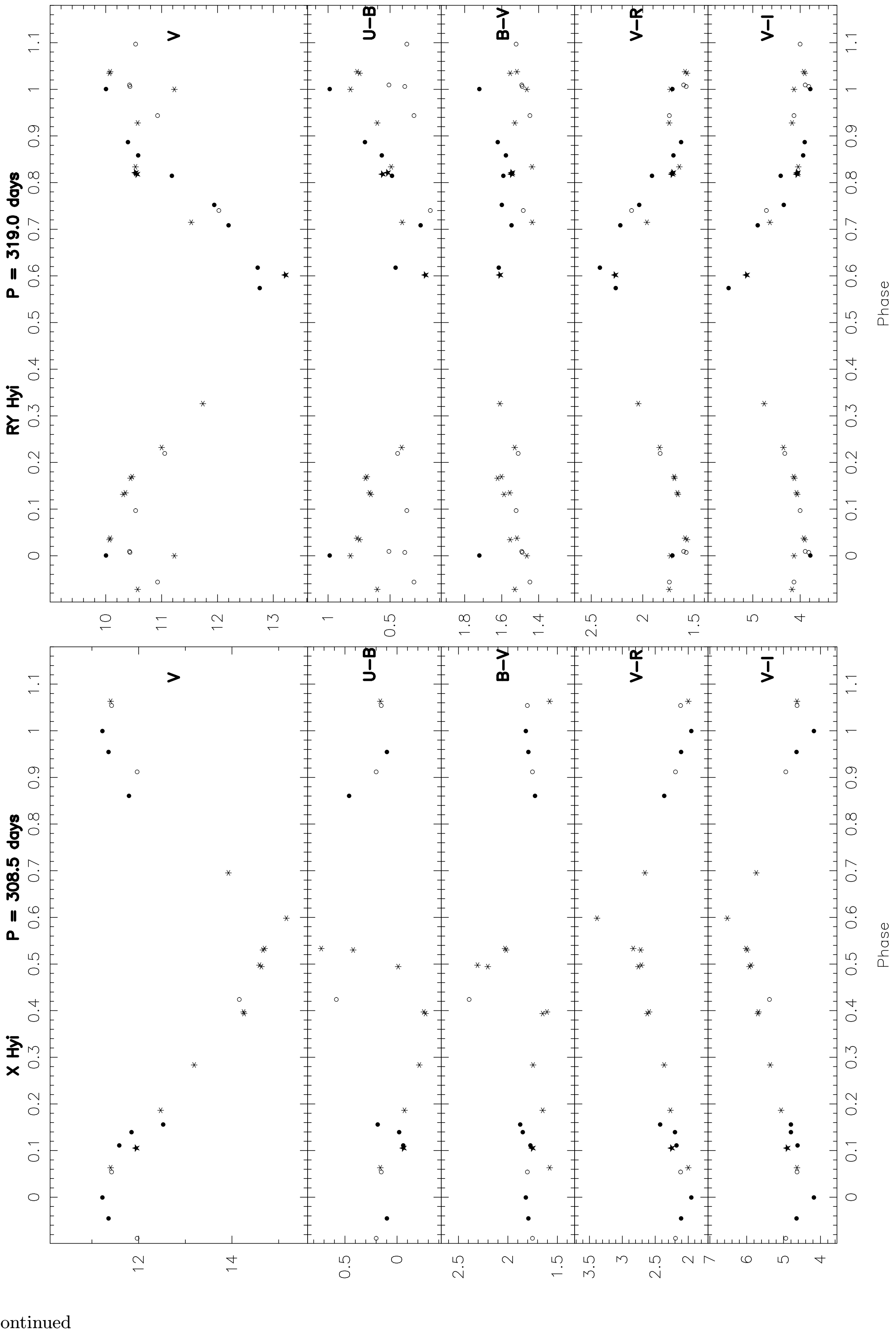

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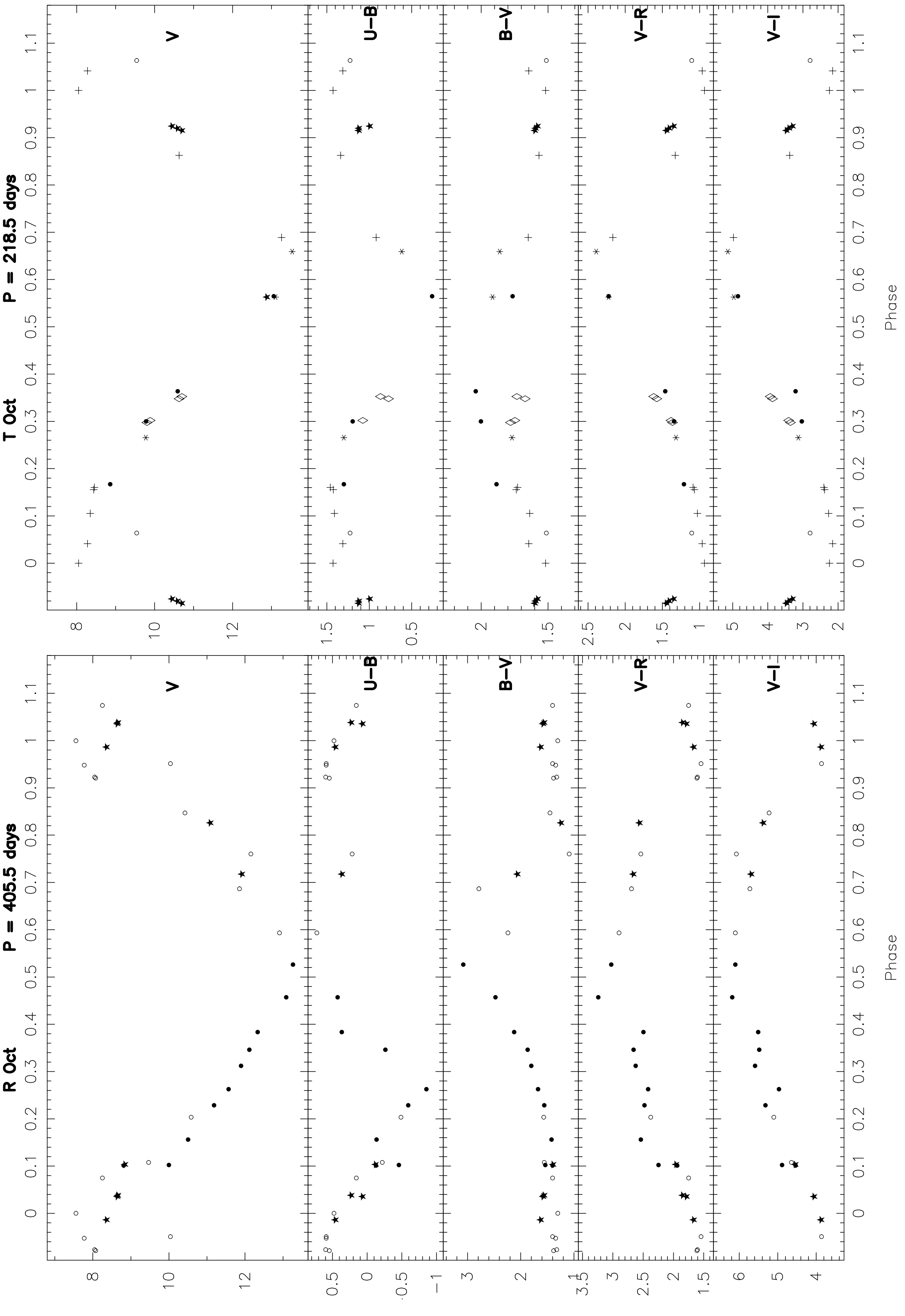

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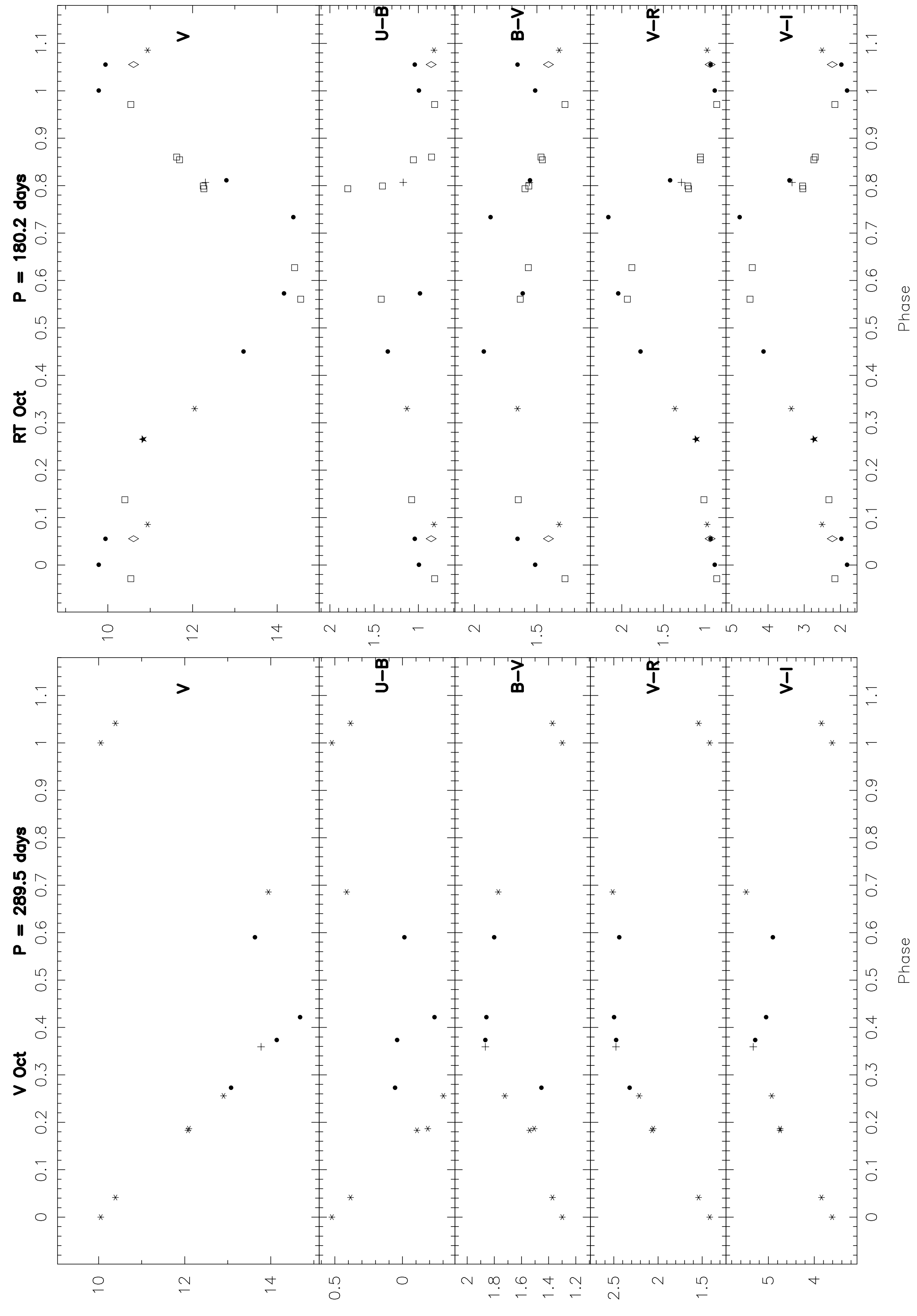

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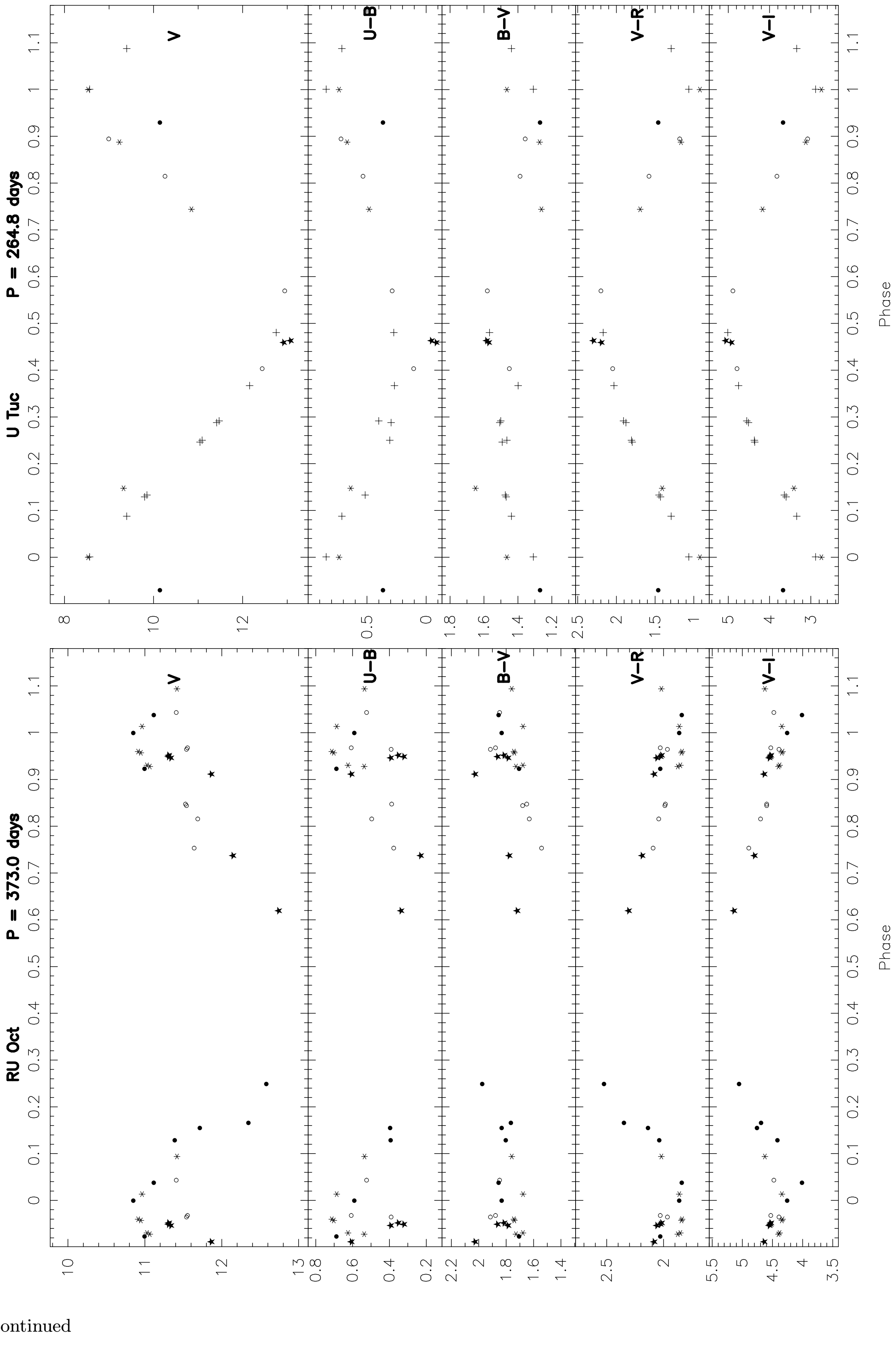

Fig. 2. continued

Table 3. New extrema of the visible magnitudes deduced from the observations and Table 1; and observed amplitude of the spectral type variations

Star	$V_{\max}$	/	$V_{\min}$	Spectral Type	$\Delta(SP)$
R Cha	7.5	/	14.2	M4.8−M7.8	3.0
V Cha	10.8	/	15.6	M6.6−M8.8	2.2
W Cha	11.9	/	16.4	M5.8−M8.3	2.5
W Hyi	11.8	/	17.1	M4.7−M7.7	3.0
X Hyi	11.2	/	16.0	M6.1−M8.3	2.2
RY Hyi	10.0	/	15.5	M5.7−M7.8	2.1
R Oct	6.4	/	13.3	M5.3−M8.4	3.1
T Oct	8.1	/	14.8	M3.1−M7.2	4.1
V Oct	10.1	/	14.7	M5.5−M7.6	2.1
RT Oct	9.8	/	14.6	M2.3−M6.8	4.5
RU Oct	10.2	/	15.0	M5.9−M7.2	1.3
U Tuc	8.0	/	14.8	M3.9−M7.1	3.2

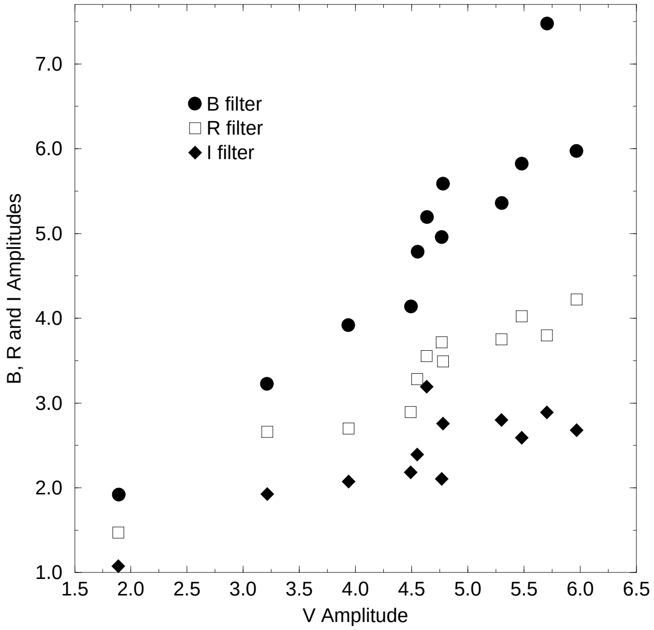

Fig. 3. Correlation between the B, R_c and I_c amplitudes with respect to the V one

3. Discussion

3.1. Light-curves

Owing to this new set of observations we can first update the V magnitude of the brightest maximum and the faintest minimum of the twelve Miras reported in Table 1. We indeed observed 11 new extrema that are given in Table 3. The new values differ most of the time by about $0.5 - 1$ mag but larger discrepancies occur for some new faintest minima.

Complete visible and colour lightcurves have been reconstructed for all the Miras except for R Cha, RY Hyi and RU Oct for which the minimum of luminosity was not precisely observed. For several stars the minimum is found after $\phi = 0.5$ (W Hyi, X Hyi, R Oct, T Oct and RT Oct). For these stars the rising branch is indeed steeper than the declining one. However the minimum is found at $\phi < 0.5$ for W Cha and V Oct and at $\phi \sim 0.5$ for V Cha and U Tuc. Finally the visible lightcurves are rather normal in the sense that no double maxima or large humps are observed.

The amplitudes of the light-curves are always decreasing with wavelength from the B filter to I_c. The largest amplitude is indeed found in B (except for W Cha, X Hyi and RT Oct where it is found in U) while the smallest one is always found in I_c. A clear relation also exists between the B, R_c or I_c amplitudes and the V amplitude (see Fig. 3). A Mira with a large amplitude in the V band (ΔV) also exhibits large ΔB, ΔR_c and ΔI_c. No such relation is found between ΔU and ΔV since the U lightcurve looks very irregular. As for the period of the lightcurves they are constant in each colours. No clear correlation were found between the amplitudes in the five filters and the period.

The shape of the colour index variations can differ strongly from one colour to another and from star to star. The $(B-V)$ colour index generally increases when the star becomes fainter and decreases when it becomes brighter. For some stars (R Cha, RY Hyi, RU Oct and U Tuc) $(B-V)$ is almost constant over the whole cycle ($\Delta(B-V) < 1$ mag). Larger $(B-V)$ varations are found for V Cha and R Oct, the two stars in our sample with a period larger than 400 days. The $(U-B)$ colour exhibits much more irregular variations than the other ones. It seems however that a small phase shift might exist between V and $(U-B)$ ($\Delta\phi \simeq 0.0-0.2$ and $(U-B)$ is in advance). The flux emitted in U and B is extremely low for stars that reach late spectral types. For this reason the Miras lacking $(U-B)$ and/or $(B-V)$ are most of the time stars close to their minimum of luminosity. Finally $(V-R_c)$ and $(V-I_c)$ vary both in phase but contrarily to the V magnitude. The stars are redder around their minimum of luminosity. No lag is detected between visual and redder light-curves. As for the colour amplitudes $(V-R_c)$ reaches a range of 1.8 mag from 0.63 to 2.44, conversely $(V-I_c)$ has a range with the same amplitude from 1.13 to 2.99. The $(B-V)$ and $(U-B)$ ranges are 1.6 (from 0.4 to 2.0) and 1.5 (0.3 to 1.8) respectively. Finally it is interesting to note that the $(U-B)$ colour index might be negative at some phases. This colour is even almost always negative for V Cha (except twice around the maximum of luminosity). However it stayed positive for W Cha, RY Hyi, T Oct, RT Oct and RU Oct. A larger flux in U than in

B has already been observed by Eggen (1975a) and Celis (1986a). The spectrum of a Mira variable can thus be very far from a blackbody distribution in this spectral interval. Celis proposed that this phenomenon could be the signature of some emission lines. But we mainly observed negative $(U-B)$ around the minimum of luminosity. It is known that very few emission lines are observed at such phases in Mira spectra (see Querci 1986b, for instance). Furthermore these lines are very narrow with respect to the width of the filters and very huge emissions (never observed around $\phi \approx 0.5$) should be present in the spectrum to increase sufficiently the flux in U. Therefore this might be in contradiction with the Celis proposition. We did not find any criteria (period or other characteristics) to separate the Miras with negative $(U-B)$ at some phases and the other ones. However all these events (39 in all) occured when the derived spectral types of the stars are between M6 and M8 (except one case for W Hyi at M5.2) although all the Miras with such spectral types do not exhibit negative $(U-B)$. Furthermore Celis (1986a) observed 11 negative $(U-B)$ in five Miras which spectral types were in the range M6.7 – M7.8. Similarly Eggen (1975aeggen75a reported such facts for R Leo around $\phi = 0$, R Car at $\phi = 0.3 - 0.4$, R Oct at $\phi = 0.2 - 0.4$ and RR Sgr at $\phi = 0.2 - 0.4$. The spectral type of these stars at these phases is known to be also in the range M6−M8 (Kholopov et al. 1985). We thus propose that negative $(U-B)$ colour indexes could be related to opacity effects occuring around spectral types M6−M8. This should however be confirmed spectroscopically and/or with model atmospheres of LPV.

3.2. Cycle-to-cycle and "odd" variations

Although the main shape (i.e. period, asymmetry, etc.) of the light-curves appears reproducible from cycle-to-cycle, variations as large as $0.5-1$ mag in the V filter can occur between successive cycles. Larger and more frequent cycle-to-cycle scatters are observed in $(U-B)$ than in the other colours. It is even sometimes difficult to define a regular variation in this colour (see RY Hyi for instance). These large cycle-to-cycle variations of short-wavelength observations argue that this spectral domain is not a good one to use for establishing the intrinsic properties of Miras. However the $(V-R_{\rm c})$ and $(V-I_{\rm c})$ lightcurves are much more regular from cycle-to-cycle. This smaller scatter of the red light-curves leads to rather small cycle-to-cycle variations of the derived spectral types as it will be shown in the next subsection.

Some of the larger scatters are found around the maximum of luminosity. For instance a deviation larger than 1.5 mag is observed in all the filters at $\phi = 0-0.1$ between the third and fifth observed cycles of T Oct. The maximum of luminosity of RU Oct was also hardly defined. The V maximum of the $n = 1$ and $n = 4$ observed cycles are very close while the maximum of the second cycle seems to be half a magnitude fainter. Furthermore the third cycle is also fainter and the shape of the lightcurve is much flatter. Similar cycle-to-cycle variations are also observed in all the other filters for this Mira. Such large scatters at maximum visual light from one cycle to another could explain the range of periods suggested for some stars. For instance Bateson & Goltz (1991) proposed for W Cha a shorter period (3 days less) than Kholopov et al. (1985). It is however difficult to confirm this shorter period with our data.

On the other hand Eggen (1975b) pointed out that the main variations from cycle-to-cycle are on the rising branch whereas the decreasing branch is less changed. Our set of data seems to follow the same trend. Around $\phi = 0.8$ a 1-mag variation has been detected in the visual lightcuve of R Cha between the first and two later cycles (the second and the fourth ones). Several observed points confirm that this event is real. The ascending branch of the first cycle is well sampled with four observations and three points have been collected in the $n = 2$ and $n = 4$ cycles. It is interesting to note that this cycle-to-cycle variation is not observed in the other filters or at least with a much smaller amplitude. Another example has been recorded around $\phi = 0.75$ in V Cha, one of the only star exhibiting a rather smooth lightcurve. The minimum of its $n = 3$ cycle seems to have been much fainter and also much redder than the first one. The star was also too faint in U and B to be measured at that time. However the following maximum seems entirely normal.

Some "odd" variations occuring during a cycle have also been recorded. For instance, just before the third observed maximum of R Oct, a sudden drop in V has been recorded. Its visual magnitude increased normally around $V = 8$ during two consecutive nights at JD = 2449669 and then ten days later at $V = 7.76$. The following night (JD = 2449680) we recorded $V = 10.03$, i.e. a sudden decline of more than 2.2 mag. The star seemed again normal 20 days later. We have checked that this "odd" measurement was real by comparing the observations of the other Miras at the same time. R Oct was the only star exhibiting such a variation that given night. Furthermore the two consecutive nights when this event occurred were very good photometrically speaking. Since the $(U-B)$ and $(B-V)$ colours were constant during these two nights a variation with a similar amplitude also occured in the B and V filters. Unfortunately no measurements were made in $R_{\rm c}$ and $I_{\rm c}$ during the first night. But $(V-R_{\rm c})$ and $(V-I_{\rm c})$ recorded during the second night are coherent with the ones collected at similar phase. Another example of a similar variation has been recorded just around the fourth recorded maximum of luminosity of RY Hyi. At JD = 2449603 the star was close to $\phi = 1$ with $V = 10.6$. Three weeks later we recorded $V = 11.2$ and then $V = 10.1$ ten days later. This Mira thus had a "odd" decline with an amplitude of 1 mag around its maximum of luminosity. Similar variations were also recorded for this star through the other filters at that time. All these "odd" events are characterized by short-term (compared to the period of the stars) variations in magnitude. They can be close to the LPV rapid variations reported by Maffei & Tosti (1995). These authors indeed observed several LPV variations in the B and I filters with amplitudes larger than 0.5 mag and durations ranging from one day to one month. Mennessier et al. (1995) also reported the probable detection of similar short-term variations by the Hipparcos satellite. Such events were actually suspected in the past in Miras and semi-regular variables (see Querci 1986a, and Schaefer 1991). We thus report two new events confirming the presence of short-term variations in oxygen-rich Miras.

3.3. Derived spectral types

Owing to the Celis method (cf. Sect. 2) the spectral type variations can be derived and then studied over the whole cycle. We actually give for the first time these variations for several Miras with a rather good sampling in phase. However let's note that M giants are usually embedded in circumstellar envelopes and their spectrum may thus be reddened. This could affect the derived spectral types. This phenomenon is neglected in this work but might be important in some stars as X Hyi and R Cha around which IRAS detected oxygen-rich envelopes.

One can see in Fig. 4 that the derived spectral type of all the selected Miras varies strongly during the cycle (from 1.3 to 4.5 subtypes). We report in Table 3 the new spectral type extrema for the Miras of our sample (updating the previously known given in Table 1). We also give in this Table 3 the amplitude of the spectral type variations. Let's recall that the lightcurves of R Cha, RY Hyi and RU Oct are not well sampled around $\phi = 0.5$. The derived spectral type amplitude of these stars is thus underestimated. In another respect since the spectral types are calculated from the $(V-R_\mathrm{c})$ and $(R_\mathrm{c}-I_\mathrm{c})$ colour indexes they vary in phase with them and contrarily to the V magnitude. This thus leads to earlier derived spectral types around the maximum of the cycle than around the minimum as it is well known. Furthermore the derived spectral types at maximum are most of the time earlier than M6 while the ones at minimum are later than M7.7. Therefore all the Miras in our sample exhibit a cycle of formation/dissociation of the VO molecule.

The derived spectral type versus phase curves are nearly regular for most of the Miras of our sample. Except for W Cha the cycle-to-cycle variations at a given phase are indeed smaller than half a subtype. This is directly related to the smaller variations recorded in the red filters than in the bluer ones: the lightcurves are indeed very regular in $(V-R_\mathrm{c})$ and $(V-I_\mathrm{c})$. The case of W Cha is interesting. All the spectral types derived during a specific cycle vary regularly but strong cycle-to-cycle variations are detected. They reach more than one subtype from one cycle to another. A few other odd variations have also been detected. For instance, the derived spectral type of RT Oct changes from M6.8 to M5.2 in less than two weeks in November 1991 and from M4.1 to M2.8 in 20 days in December 1995. However the regularity of the derived spectral type variations is most of the time well verified for the other stars.

Table 4. Derived visual absolute magnitude at maximum light and distance of the observed Mira variables

Star	M_V^max	d (pc)
R Cha	−1.66	650
V Cha	−0.92	1840
W Cha	−1.03	3230
W Hyi	−1.60	4460
X Hyi	−0.94	2500
RY Hyi	−1.19	1590
R Oct	−1.64	710
T Oct	−2.17	1020
V Oct	−1.20	1640
RT Oct	−2.24	2230
RU Oct	−1.01	2160
U Tuc	−1.98	1160

3.4. Derivation of luminosities and distances

The distance of the studied stars can be estimated from their *UBVRI* photometry. Celis (1986b, Eq. (5)) indeed showed that the visual absolute magnitude at maximum light (M_V^max) of Miras can be determined from their period and their spectral type at $\phi = 0$. We prefered to use this method than the ones proposed by Celis (1995) because the dependence of M_V with respect to the period of the star is explicitely taken into account in agreement with all other methods. From our observed V_max and the corresponding derived spectral type we then report in Table 4 the M_V^max and the distance of all the Miras of our sample. The interstellar extinction (A_V) was estimated by using the results of Arenou et al. (1992). They compared their model of galactic interstellar extinction with previous works and conclude that their estimates of A_V are very good for regions having $A_V < 0.5$ mag (case for all the Miras of our sample). Finally let's note that the deduced distances might be slightly overestimated because the actual maximum of the cycle (and hence its derived spectral type) has perhaps not been observed.

It is interesting to see how distances derived from these relations and our data compare with those derived by

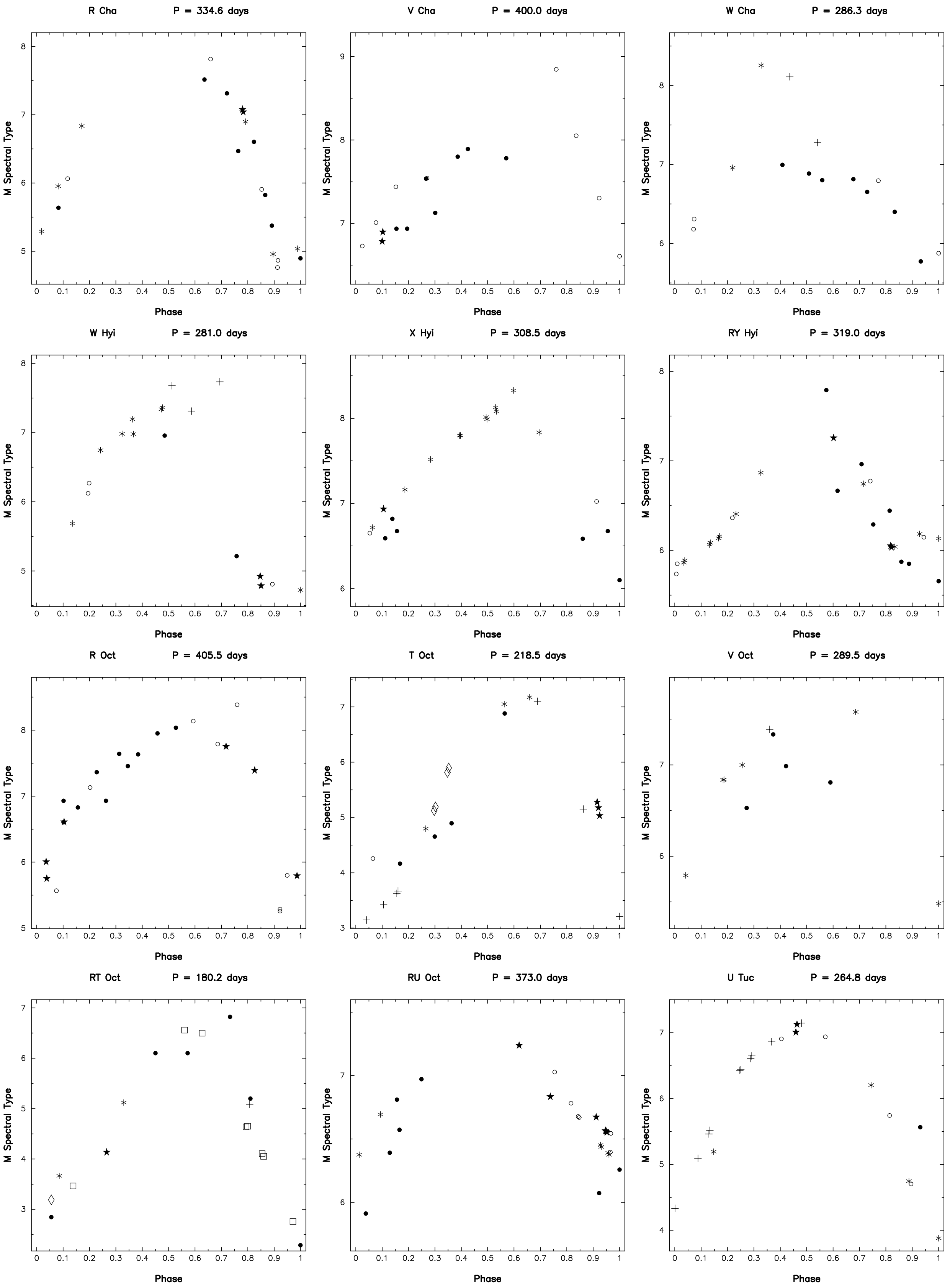

Fig. 4. The derived spectral type variations of the twelve Miras during their cycle. The different symbols correspond to the succesive cycles observed (same as Fig. 2)

other methods. Let's first point out that the best distances come from infrared magnitudes for Miras in the LMC (disregarding parallaxes because the sample is so small). We found eight stars in our sample with previously known distances (Celis 1981; Jura & Kleinmann 1992 or Celis 1995). They are compared in Table 5. Celis (1981) derived the distance from his ($V_{\rm max}$, P, $SP_{\rm max}$) relation while Jura & Kleinmann (1992) used the (P, $M_{\rm K}$) relation of Feast et al. (1989) modified by Wood (1990). Finally Celis (1995) used purely photometric and/or spectral-photometric methods. Except for X Hyi and one previous estimate of R Oct our derived distances are consistent with those found in the literature (the mean difference is less than 22%). The large discrepancy found between our distance estimate of X Hyi and the Jura & Kleinmann's one can not be explained easily. The maximum we observed is rather well defined and no large cycle-to-cycle variations are found for this star. But we can not exclude a-priori that the cycles we observed were not peculiar. Furthermore X Hyi is known to have an oxygen-rich envelope (see its LRS spectral classification). This might affect strongly the colours we observed and thus the derived spectral types and distance. On the other hand Jura & Kleinmann did not find any photometry of X Hyi in the K band. They deduced its distance by estimating its K magnitude from the IRAS flux at 12 μm and the Two Micron Sky Survey flux at 2 μm. However the K-magnitude may be poorly estimated from the 2 and 12 μm fluxes because of the circumstellar envelope surrounding this star. This peculiar Mira thus differs from a "normal" star and should be treated more carefully. As for R Oct our distance determination is larger than the Celis's ones and than the distance deduced from the period-infrared luminosity relation derived by Feast et al. (1989). The K magnitude of R Oct has been found in Catchpole et al. (1979). Our estimate is certainly the worst one since the observed visible maximum of this star varies strongly from one cycle to another (up to ~ 1 mag). The actual maximum is therefore badly defined. This could also explain the discrepancy reported in Table 5 for RU Oct.

In order to confirm that this method could actually lead to rather good distance estimates we also compare in Table 5 the distance of some other Miras calculated with this method and previous independent determinations. The main difficulty was to find $UBVRI$ observations at $\phi = 0$. We only found such observations of o Cet around its maximum of luminosity in Mendoza (1967) and R Leo was observed by Eggen (1975a) at $\phi = 0.965$. Some other Miras were also observed by Eggen (1975a) around $\phi = 0$. The $UBV(RI)_{\rm J}$ data of Mendoza and the $UBV(RI)_{\rm K}$ data of Eggen were converted into the Cousins system using the colours transformations derived by Bessel (1983) and Bessel & Weis (1987) respectively. Finally Celis (1986b) also reported for some Miras $V_{\rm max}$ and $M_V^{\rm max}$ calculated with the same method as the one we use in the present paper.

The previously known distances of these stars were found in Jura & Kleinmann (1992); Celis (1995) and Haniff et al. 1995 (who used the (P, $M_{\rm K}$) relation of Feast et al. 1989). o Cet and R Leo are the only Miras for which trigonometric parallaxes exist and direct estimate of their distance can be made (Jenkins 1952 and Gatewood 1992 respectively). We do not report the distances deduced by Eggen himself (1975b) because they differ to a great extent from ours and more recent ones (this was first pointed out by Celis 1981). Eggen actually deduced his period-luminosity relation from a correlation found between the period and the $(R-I)$ colour at $\phi = 0.25$ derived with nine stars only. Our data do not fit his (P, $R-I$) relation transformed into the Cousins system using Bessel & Weis (1987). We therefore question this relation and that could explain why Eggen derived distances in disagreement with all other estimates.

Finally the distance we deduced for o Cet is in good agreement with its parallax and other estimations but a difference of $\sim 60\%$ and sometimes larger with respect to other works is found for R Leo. This discrepancy could easily be explained by the lack of $UBVRI$ data at the real maximum of luminosity of this star. A rather large departure is also found between our derived distance of R Hya and the one of Celis (1995) whereas it is quite close to the two other previous determinations. However the agreement between our distance determinations and the previous ones is actually rather good for all the other stars (mean departure smaller than $\sim$ 30%).

The photometric method proposed by Celis leads thus to rather good distance estimates IF $UBVRI$ data at the REAL maximum of luminosity are available. The mean departure with respect to other determinations is actually close to their own error bars. However we have already pointed out that the lightcurve of some Miras exhibits strong cycle-to-cycle variations especially around their maximum of luminosity. Since we derived their distance from their magnitude and colours at that time it actually might not be very accurate and several maxima should be observed to increase the accuracy of the method.

4. Conclusion

We have presented a photometric monitoring of twelve oxygen-rich Miras over a 4-year period. The properties of these southern hemisphere variables were rather poorly known before this study. This work has considerably improved the set of available LPV light-curves in visible colours: between 53 and 140 $UBV(RI)_{\rm c}$ measurements are presented for each star covering between three and seven successive cycles. This allowed us to reconstruct the light-curves in all the colours. We then derived the spectral type of these Long Period Variables at all the epochs of the observations. Spectral type versus phase variations over a whole cycle are therefore given for the first time together with the *UBVRI* light-curves. New photometric parameters (visible and spectral type extrema, spectral type amplitudes, etc.) have been derived. We have also proposed a period for V Cha ($P = 400 \pm 10$ days) and W Cha is confirmed as being an oxygen-rich Mira. Moreover the repeatability of the visible and colour light-curves during the successive cycles has been discussed: strong variations in all the filters are reported some of them over quite a short term. We thus confirm that rapid variations are certainly real in Miras. We finally have derived the distance of these twelve LPV and shown that rather good estimates can be obtained from *UBVRI* data at maximum light.

This paper shows once again that broad-band photometry is a powerful tool for studying Long-Period Variables. Furthermore these cool stars emit the largest part of their energy in the infrared. Simultaneous observations from the *U* filter up to the infrared could help in the modelling of these stars as Le Bertre already did for R For (1988). Furthermore the cycle-to-cycle variations are smaller at longer wavelength where intrinsic properties of Miras can then be derived more accurately. Future monitoring of LPV should thus cover a larger and redder spectral domain than the one studied here. In another respect we have seen that the real maximum of luminosity has to be observed to determine the distance of these stars. This and the cycle-to-cycle variation studies at all wavelengths require collection of data over a large number of successive cycles and with a good sampling in time during each period (i.e. at leat two or three points per month). Such programs would require a large amount of telescope time and emphasize the utility of telescopes dedicated to stellar photometry.

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Table 2. V magnitudes, $UBV(RI)_c$ colours and derived spectral types

JD (2448000 +)	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	Spect. Type
R Cha						
547.5	13.80	0.20	1.59	3.11		M7.5
576.5	11.67	0.32	1.38	2.26	5.17	M7.3
590.5	11.06		1.35	1.93	4.43	M6.5
610.5	10.33	0.38	1.29	1.78	4.47	M6.6
624.5	9.44	0.57	1.32	1.52	3.87	M5.8
633.5	8.64	0.70	1.43	1.33	3.54	M5.4
669.5	7.83	0.68	1.58	1.37	3.20	M4.9
697.5	8.84	0.27	1.59	1.51	3.73	M5.6
930.5	12.07	0.32	1.96	2.38	5.06	M7.1
931.5	12.02	0.29	1.99	2.36	5.02	M7.0
1224.5	13.02	−0.05	1.37	2.64	5.72	M7.8
1289.5	9.31	0.71	1.36	1.52	3.92	M5.9
1309.5	7.95	0.76	1.50	1.21	3.12	M4.8
1310.5	7.93	0.85	1.48	1.24	3.19	M4.9
1338.5	8.09	0.70	1.55		3.33	
1377.5	9.27	0.30	1.56	1.68	4.07	M6.1
1603.5	11.88		1.70	2.00	4.76	M6.9
1638.5	8.35	0.73	1.30	1.24	3.26	M5.0
1669.5	8.47	0.51	1.43	1.29	3.30	M5.0
1679.5	8.72	0.41	1.47	1.37	3.48	M5.3
1700.5	9.58	0.10	1.48	1.64	3.98	M6.0
1730.5	10.97	−0.07	1.54	2.02	4.72	M6.8
V Cha						
547.5	12.93	−0.01	1.64	2.62		M6.9
576.5	13.58	−0.34	1.78	2.56	5.48	M7.5
590.5	13.97		1.86	2.55	5.18	M7.1
624.5	14.44			1.94	5.38	M7.8
639.5	14.62	−2.73	3.13	2.71	5.81	M7.9
697.5	14.50	−1.66	2.95	2.77	5.77	M7.8
931.5	11.94	−0.23	1.79	2.27	4.91	M6.9
1309.5	11.91	−0.22	1.61	2.16	4.75	M6.8
1310.5	11.93	−0.05	1.60	2.22	4.86	M6.9
1338.5	12.74	−0.37	1.64		5.17	
1377.5	13.68	−0.28	1.78	2.61	5.51	M7.5
1573.5	15.61			4.26	7.49	M8.8
1603.5	13.49		2.10	2.67	5.90	M8.0
1638.5	12.10	0.27	1.40	2.21	5.14	M7.3
1669.5	10.83	0.31	1.34	1.82	4.49	M6.6
1679.5	10.91		1.36	1.90	4.61	M6.7
1700.5	11.38	−0.01	1.37	2.10	4.88	M7.0
1730.5	12.11	−0.22	1.42	2.32	5.29	M7.4
W Cha						
547.5	15.24		2.39	2.67		M7.0
576.5	14.63		2.21	1.90	4.72	M6.9
590.5	15.05			2.37	4.86	M6.8
624.5	13.81	0.31	1.62	2.29	4.83	M6.8
639.5	13.44	0.09	1.29	1.96	4.57	M6.7
669.5	12.90	0.35	1.65	2.11	4.46	M6.4
697.5	12.05	0.57	1.74	1.67	3.86	M5.8
1224.5	13.86		1.60	2.23	4.79	M6.8
1289.5	11.94	0.22	1.55	1.67	3.93	M5.9
1309.5	12.45	0.15	1.69	1.83	4.20	M6.2
1310.5	12.51	0.25	1.68	1.90	4.31	M6.3
1338.5	13.55	0.13	1.61		4.73	
1638.5	13.80	0.02	1.71	2.18	4.88	M7.0
1669.5	16.30			3.67	6.66	M8.3
1700.5	16.43			3.27	6.30	M8.1
1730.5	15.19			2.12	5.08	M7.3
W Hyi						
547.5	17.01	0.32		2.64		M7.0
624.5	14.79	−0.50	0.89	1.21	3.44	M5.2
930.5	12.23	0.78	1.19	1.20	3.24	M4.9
931.5	12.09	0.76	1.23	1.16	3.15	M4.8
1224.5	12.34	0.84	1.33	1.23	3.15	M4.8
1309.5	13.86	−0.10	1.45	1.80	4.15	M6.1
1310.5	13.88	0.05	1.42	1.82	4.26	M6.3
1535.5	11.83	0.75	1.25	1.16	3.11	M4.7
1573.5	12.82	0.31	1.36	1.50	3.77	M5.7
1603.5	14.28	0.00	1.24	1.98	4.65	M6.7
1626.5	15.39	−0.53	1.44	2.14	4.88	M7.0
1637.5	15.96		1.39	2.37	5.14	M7.2
1638.5	15.67			2.06	4.84	M7.0
1668.5	16.48			2.08	5.11	M7.3
1669.5	16.68	−0.54		2.42	5.28	M7.4
1679.5	17.13		1.32	2.71	5.66	M7.7
1700.5	16.72			2.33	5.20	M7.3
1730.5	16.89			3.04	5.89	M7.7
X Hyi						
547.5	11.79	0.46	1.73	2.36		M6.6
576.5	11.35	0.10	1.79	2.11	4.65	M6.7
590.5	11.23		1.82	1.95	4.18	M6.1
624.5	11.59	−0.06	1.77	2.18	4.62	M6.6
633.5	11.85	−0.02	1.85	2.20	4.80	M6.8
638.5	12.53	0.19	1.88	2.42	4.80	M6.7
931.5	11.95	−0.06	1.75	2.25	4.90	M6.9
1180.5	11.97	0.20	1.75	2.19	4.93	M7.0
1224.5	11.41	0.15	1.80	2.12	4.64	M6.7
1338.5	14.15	0.58	2.39		5.38	
1535.5	11.40	0.16	1.58	2.00	4.64	M6.7
1573.5	12.47	−0.07	1.65	2.27	5.07	M7.2
1603.5	13.19	−0.21	1.75	2.37	5.36	M7.5
1637.5	14.26	−0.27	1.65	2.62	5.70	M7.8
1638.5	14.25	−0.26	1.60	2.59	5.68	M7.8
1668.5	14.63	−0.01	2.20	2.76	5.93	M8.0
1669.5	14.59		2.31	2.71	5.88	M8.0
1679.5	14.66	0.42	2.02	2.72	5.99	M8.1
1680.5	14.70	0.73	2.03	2.84	6.02	M8.1
1700.5	15.16			3.38	6.53	M8.3
1730.5	13.92			2.66	5.74	M7.8

Table 2. continued

JD (2448000 +)	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	Spect. Type
RY Hyi						
547.5	12.73	0.46	1.62	2.42		M6.7
576.5	12.20	0.25	1.55	2.22	4.90	M7.0
590.5	11.94		1.60	2.03	4.35	M6.3
610.5	11.18	0.48	1.59	1.91	4.41	M6.4
624.5	10.58	0.57	1.58	1.70	3.94	M5.9
633.5	10.39	0.70	1.62	1.62	3.90	M5.9
669.5	10.00	0.99	1.72	1.71	3.79	M5.7
852.5	12.76			2.26	5.51	M7.8
930.5	10.56	0.56	1.55	1.71	4.07	M6.0
931.5	10.53	0.52	1.54	1.71	4.05	M6.0
1180.5	13.22	0.22	1.61	2.27	5.13	M7.3
1224.5	12.02	0.18	1.48	2.11	4.72	M6.8
1289.5	10.92	0.30	1.45	1.74	4.14	M6.1
1309.5	10.44	0.38	1.49	1.58	3.82	M5.7
1310.5	10.42	0.51	1.49	1.61	3.90	M5.8
1338.5	10.53	0.37	1.52		4.00	
1377.5	11.06	0.44	1.51	1.83	4.32	M6.4
1535.5	11.53	0.40	1.43	1.96	4.64	M6.7
1573.5	10.53	0.49	1.44	1.64	4.04	M6.0
1603.5	10.57	0.60	1.53	1.74	4.17	M6.2
1626.5	11.23	0.82	1.46	1.73	4.13	M6.1
1637.5	10.07	0.75	1.55	1.57	3.90	M5.9
1638.5	10.08	0.77	1.52	1.59	3.92	M5.9
1668.5	10.31	0.65	1.59	1.66	4.06	M6.1
1669.5	10.35	0.67	1.56	1.66	4.08	M6.1
1679.5	10.44	0.70	1.62	1.69	4.12	M6.1
1680.5	10.47	0.69	1.60	1.69	4.14	M6.2
1700.5	11.00	0.41	1.53	1.84	4.36	M6.4
1730.5	11.74		1.61	2.04	4.76	M6.9
R Oct						
525.5	10.00	−0.46	1.53	2.25	4.89	M6.9
547.5	10.50	−0.13	1.42	2.54		M6.8
576.5	11.19	−0.59	1.55	2.48	5.32	M7.4
590.5	11.56	−0.86	1.68	2.42	4.98	M6.9
610.5	11.90		1.80	2.62	5.59	M7.6
624.5	12.11	−0.26	1.87	2.66	5.48	M7.5
639.5	12.34	0.36	2.12	2.50	5.51	M7.6
669.5	13.09	0.43	2.47	3.24	6.18	M8.0
697.5	13.26		3.09	3.03	6.10	M8.0
930.5	8.80	−0.13	1.40	1.93	4.53	M6.6
931.5	8.85	−0.12	1.39	1.96	4.54	M6.6
1180.5	11.92	0.36	2.06	2.66	5.69	M7.8
1224.5	11.09		1.24	2.56	5.38	M7.4
1289.5	8.36	0.46	1.62	1.66	3.87	M5.8
1309.5	8.64	0.07	1.58	1.78	4.05	M6.0
1310.5	8.66	0.23	1.56	1.85		M5.8
1338.5	9.46	−0.22	1.55		4.64	
1377.5	10.59	−0.49	1.57	2.37	5.09	M7.1
1535.5	12.91	0.72	2.24	2.90	6.10	M8.1
1573.5	11.86		2.79	2.69	5.73	M7.8
1603.5	12.15	0.22	1.09	2.54	6.07	M8.4
1638.5	10.41		1.45		5.22	
1668.5	8.07	0.54	1.39	1.62		M5.3
1669.5	8.04	0.60	1.32	1.61		M5.3
1679.5	7.76	0.59	1.35			
1680.5	10.03	0.59	1.40	1.54	3.86	M5.8
1700.5	7.56	0.48	1.31			
1730.5	8.25	0.15	1.40	1.75		M5.6

Table 2. continued

JD (2448000 +)	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	Spect. Type
T Oct						
547.5	8.86	1.30	1.88	1.21		M4.2
576.5	9.78	1.20	2.00	1.35	3.03	M4.7
590.5	10.59		2.04	1.46	3.20	M4.9
634.5	13.06	0.26	1.76	2.23	4.85	M6.9
852.5	12.88					
929.5	10.70	1.12	1.60	1.45	3.47	M5.3
930.5	10.59	1.12	1.59	1.41	3.39	M5.2
931.5	10.45	0.99	1.58	1.35	3.29	M5.0
1180.5	9.54	1.22	1.51	1.11	2.81	M4.3
1224.5	9.77	1.30	1.77	1.32	3.13	M4.8
1289.5	13.10		1.91	2.22	4.97	M7.0
1310.5	13.53	0.62	1.86	2.39	5.14	M7.2
1535.5	13.26	0.92	1.65	2.17	4.98	M7.1
1573.5	10.63	1.34	1.57	1.33	3.38	M5.2
1603.5	8.05	1.43	1.52	0.94	2.25	M3.2
1612.5	8.28	1.31	1.64	0.96	2.15	M3.1
1626.5	8.35	1.41	1.64	1.03	2.27	M3.4
1637.5	8.44	1.42	1.74	1.07	2.38	M3.6
1638.5	8.46	1.46	1.73	1.09	2.40	M3.7
1668.5	9.80		1.78	1.36	3.36	M5.1
1669.5	9.88	1.08	1.75	1.38	3.41	M5.2
1679.5	10.63	0.77	1.67	1.58	3.87	M5.8
1680.5	10.70	0.87	1.73	1.62	3.93	M5.9
V Oct						
547.5	13.07	0.05	1.45	2.32		M6.5
576.5	14.14	0.04	1.87	2.47	5.29	M7.3
590.5	14.68	−0.23	1.86	2.49	5.05	M7.0
639.5	13.64	−0.01	1.80	2.44	4.90	M6.8
1535.5	13.94	0.41	1.77	2.51	5.48	M7.6
1626.5	10.05	0.52	1.30	1.41	3.61	M5.5
1638.5	10.39	0.38	1.37	1.54	3.84	M5.8
1679.5	12.08	−0.11	1.54	2.07	4.74	M6.8
1680.5	12.10	−0.19	1.51	2.06	4.74	M6.8
1700.5	12.90	−0.30	1.72	2.21	4.93	M7.0
1730.5	13.77		1.87	2.48	5.33	M7.4
RT Oct						
525.5	13.20	1.35	1.93	1.77	4.12	M6.1
547.5	14.17	0.98	1.62	2.04		M6.1
576.5	14.38		1.87	2.16	4.78	M6.8
590.5	12.80		1.55	1.42	3.41	M5.2
624.5	9.79	0.99	1.51	0.88	1.81	M2.3
634.5	9.94	1.04	1.65	0.94	1.98	M2.8
852.5	10.84			1.11	2.72	M4.1
1180.5	10.94	0.82	1.32	0.97	2.51	M3.7
1224.5	12.05	1.13	1.65	1.36	3.36	M5.1
1310.5	12.30	1.17	1.56	1.28	3.34	M5.1
1535.5	10.60	0.86	1.41	0.94	2.22	M3.2
1626.5	14.56	1.42	1.63	1.93	4.50	M6.6
1638.5	14.41		1.57	1.88	4.44	M6.5
1668.5	12.27	1.80	1.60	1.20	3.04	M4.6
1669.5	12.25	1.41	1.57	1.21	3.05	M4.7
1679.5	11.69	1.06	1.46	1.05	2.73	M4.1
1680.5	11.62	0.85	1.47	1.06	2.69	M4.1
1700.5	10.54	0.82	1.27	0.86	2.15	M2.8
1730.5	10.40	1.08	1.65	1.01	2.32	M3.5

Table 2. continued

JD (2448000 +)	V	$U-B$	$B-V$	$V-R_c$	$V-I_c$	Spect. Type
RU Oct						
547.5	10.99	0.69	1.71	2.03		M6.1
576.5	10.85	0.59	1.83	1.86	4.26	M6.3
590.5	11.11		1.85	1.84	4.01	M5.9
624.5	11.39	0.39	1.80	2.04	4.42	M6.4
634.5	11.71	0.40	1.83	2.14	4.76	M6.8
638.5	12.35		1.77	2.35	4.69	M6.6
669.5	12.58		1.98	2.52	5.06	M7.0
929.5	11.34	0.39	1.78	2.06	4.55	M6.6
930.5	11.31	0.32	1.86	2.03	4.53	M6.6
931.5	11.31	0.35	1.81	2.02	4.53	M6.6
1180.5	12.74	0.34	1.72	2.31	5.14	M7.2
1224.5	12.15	0.23	1.78	2.19	4.80	M6.8
1289.5	11.86	0.61	2.03	2.08	4.64	M6.7
1309.5	11.54	0.39	1.91	1.97	4.39	M6.4
1310.5	11.55	0.61	1.88	2.03	4.52	M6.5
1338.5	11.41	0.52	1.85		4.48	
1603.5	11.64	0.38	1.54	2.09	4.89	M7.0
1626.5	11.69	0.49	1.63	2.04	4.70	M6.8
1637.5	11.54		1.68	1.99	4.60	M6.7
1638.5	11.52	0.39	1.65	1.98	4.59	M6.7
1668.5	11.06	0.54	1.73	1.88	4.40	M6.5
1669.5	11.03	0.62	1.68	1.85	4.38	M6.4
1679.5	10.95	0.70	1.74	1.84	4.35	M6.4
1680.5	10.91	0.71	1.74	1.84	4.33	M6.4
1700.5	10.96	0.69	1.68	1.86	4.34	M6.4
1730.5	11.42	0.54	1.76	2.02	4.63	M6.7
U Tuc						
525.5	10.14	0.36	1.27	1.46	3.67	M5.6
930.5	12.92	−0.09	1.57	2.19	4.92	M7.0
931.5	13.08	−0.05	1.58	2.30	5.05	M7.1
1180.5	12.43	0.10	1.45	2.05	4.79	M6.9
1224.5	12.95	0.28	1.58	2.20	4.88	M6.9
1289.5	10.26	0.54	1.39	1.58	3.81	M5.7
1310.5	9.00	0.72	1.35	1.18	3.09	M4.7
1338.5	8.53	0.74	1.47	0.92	2.75	M3.9
1377.5	9.33	0.64	1.65	1.41	3.41	M5.2
1535.5	10.85	0.48	1.26	1.69	4.17	M6.2
1573.5	9.23	0.67	1.27	1.17	3.12	M4.7
1603.5	8.56	0.85	1.31	1.07	2.89	M4.3
1626.5	9.40	0.71	1.44	1.29	3.34	M5.1
1637.5	9.80		1.47	1.43	3.60	M5.5
1638.5	9.85	0.52	1.47	1.45	3.64	M5.5
1668.5	11.04		1.49	1.80	4.36	M6.4
1669.5	11.09	0.31	1.47	1.80	4.37	M6.4
1679.5	11.42	0.30	1.51	1.88	4.51	M6.6
1680.5	11.47	0.40	1.50	1.91	4.55	M6.6
1700.5	12.16	0.27	1.40	2.03	4.75	M6.9
1730.5	12.75	0.27	1.57	2.17	5.01	M7.1

Table 5. Comparison of the Mira distances calculated in Table 4 with previous and independent determinations. Distance of other Miras calculated from $UBVRI$ data found in the literature are also determined and compared to other determinations

Star	Present work (pc)	Literature (pc)	Diff. (%)
R Cha	650	$522^{(C95)}$	25
W Hyi	4460	$4200^{(JK)}$	6
X Hyi	2500	$890^{(JK)}$	180
RY Hyi	1590	$1300^{(JK)}$	22
R Oct	710	$639^{(C81)}$	11
		$322^{(C95)}$	120
		$499^{(*)}$	42
T Oct	1020	$1100^{(JK)}$	7
RU Oct	2160	$1300^{(JK)}$	66
U Tuc	1160	$970^{(JK)}$	20
		$991^{(C81)}$	17
		$1071^{(C95)}$	8
o Cet	89	$77^{(J52)}$	16
		$100^{(JK)}$	11
		$110^{(HST)}$	19
		$62^{(C95)}$	43
T Col	570	$580^{(JK)}$	2
		$647^{(C95)}$	12
T Gru	1360	$1900^{(JK)}$	28
		$2101^{(C95)}$	35
T Hor	940	$1100^{(JK)}$	14
		$1361^{(C95)}$	31
R Hya	140	$110^{(JK)}$	27
		$125^{(HST)}$	12
		$84^{(C95)}$	67
RU Hya	650	$640^{(JK)}$	1
		$568^{(C95)}$	14
R Leo	180	$120^{(G92)}$	50
		$99^{(JK)}$	82
		$110^{(HST)}$	63
		$91^{(C95)}$	98
S Lib	1020	$1800^{(JK)}$	43
		$1678^{(C95)}$	39
R Vir	470	$500^{(JK)}$	6
S Vir	420	$450^{(JK)}$	7
		$294^{(C95)}$	43

(J52): Jenkins (1952).
(C81): Celis (1981).
(G92): Gatewood (1992).
(HST): Haniff et al. (1995).
(JK): Jura & Kleinmann (1992).
(C95): Celis (1995).
(*): from the (P, M_K) relation of Feast et al. (1989) - see text.