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PERIODS OF 54 KNOWN MIRAS AND OF 16 NEW ONES IN SCORPIUS

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An area covering 3.85 square degrees centred at $l = 353\overset{\circ}{.}0$ and $b = +3\overset{\circ}{.}0$ and extending in RA from $17^{\rm h}11^{\rm m}$ to $17^{\rm h}19^{\rm m}$ and in Dec from $-32°00'$ to $-34°18'$ (epoch 2000.0) has been searched for faint Mira type stars and their periods of light variations. An important feature of this field is its low foreground obscuration and the uniform areal distribution of the obscuring matter as shown by earlier investigations at the Lund Observatory concerning the local galactic structure in this region (Roslund, 1966). The purpose of the present investigation has been to enquire into the potentiality of studying with medium sized telescopes the spheroidal halo of Pop II stars around the galactic centre with the help of faint Mira type variables in low foreground obscuration fields like ours. 16 new Mira variables were detected in the field and their periods of light variations determined together with 54 stars already known to be variable.

The search was made by using Kodak l03a-E plates photographed in red light through a Schott RG 1 filter with the 50/65 cm Uppsala-Schmidt telescope at Mount Stromlo Observatory in Australia at intervals of about 30 days during an observing season of usually seven months a year from April to October. The observations span five seasons from April 1967 to October 1971 and cover a total length of 1634 days. Altogether 30 red search plates were obtained.

Each plate was calibrated using R magnitudes in the $UBVRI$ system (Johnson, 1964) measured photoelectrically for forty stars of spectral class M with the 1 metre ESO photometric telescope at La Silla in Chile.

The limiting magnitude of the plates is about $R = 14.5$ before the effect of the seeing causes the photographic calibration curve to level off. For a star to be assigned a Mira type variable, its light curve must be known for a minimum of one and a half magnitudes, setting the limiting magnitude at maximum light for this search of faint Mira type stars at $R = 13.0$. This magnitude should correspond to about $V = 14.5$ for Mira type variables of early spectral class M and to $V = 15.5$ for those of late spectral class, not taking into account any interstellar reddening beyond that encountered in the local spiral arm.

The stars that vary in brightness were found by blinking sixteen plates arranged in fourteen pairs. As only variables with large light variations were looked for, a simple blinking device was invented. It consisted of two reading projectors for microfilm adjusted to project the same field of two plates on the same screen so that their stellar images overlapped. The blinking effect was obtained by alternatively switching the light off and on between the two projectors in quick succession. By this means, approximately 150 variables with amplitudes larger than about two magnitudes were detected. Seventy of these stars showed regular or nearly regular light variations with periods longer than 150 days. They are here referred to as Mira type variables and are listed with their main characteristics in the Catalogue at the end of the article. 16 of the stars in the Catalogue have not been known to be variable.

For stars with image sizes larger than the seeing diameter, their apparent magnitudes were obtained by moving the plate with a micrometer screw a distance corresponding to the image diameter of the stars seen projected on the screen. This method was felt to be superior to the iris photometer method as most star images in this densly populated field were seriously disturbed by neighbouring stars. A mean error of 0.2 magnitude in one measurement was estimated from measurements on several plates of stars of constant brightness.

This procedure could not be adapted to stars just above the limiting magnitude of the plates as the image size of these stars is practically the same as the seeing diameter over a wide range of magnitudes. Their magnitudes had instead to be derived from the visible character of the stellar images which depends on a number of factors as the focusing and guiding of the telescope, the atmospheric seeing, extinction and sky glow and photographic processing. These factors change from plate to plate and can, if not controlled, cause an ordinary star of constant brightness to be mistaken for a variable star. The factors can to some extent be controlled by monitoring the appearance of the photometric standard stars. However, the eye has a tendency to set up its own rules for judging the magnitudes of faint stars, making their magnitudes liable to large errors.

A lot of attention was paid to the problem of getting reliable magnitudes for the faint stars. To be sure that the photometric plates had about the same limiting magnitude, we ascertained that almost the same number of stars considered to be Mira type variables appeared on each plate.

In order to get information on spectral types of the Mira variables, three long-exposures in the near infrared on Kodak I-N plates behind a Schott RG5 filter were obtained on widely separated occasions with the 50/65 cm Uppsala-Schmidt telescope equipped with an objective prism giving a dispersion of 2200 Å/mm at the atmospheric A band. The classification of the spectra followed the criteria described by Nassau and Velghe (Nassau and Velghe, 1964) but the spectra were then transformed to the Mount Wilson classification system (Adams et al., 1926) by means of the relation established by Blanco (Blanco, 1964). As the objective prism plates in this study only reach stars down to about $I = 10.5$, the faintest Mira type variables found of early spectral class M cannot be expected to leave a classifiable spectrum even at maximum light.

The spectral type was determined only for those Mira type variables which happened to have an established maximum within a time interval of ten per cent of their period of light variations from the date of exposure of one of the three objective prism plates. Some of these stars could not, however, be classified because their spectra were severely distorted by those of brighter stars in this congested star field. As a consequence, spectral classes could only be assigned to one half of the Mira variables found in the studied area.

Only ten stars in the Catalogue were bright enough to show up on the photometric plates at minimum light – Table 1. The mean amplitude of the light variations for the five brightest stars is 3.4 magnitudes in red light, but it should be remembered that all the stars at their minima are just above the sensitivity for the plates to produce an image, resulting in large errors in determining the amplitude.

Table 1. Mira type variables with observed minima.

No	R (mag)	ΔR (mag)	P (day)	Sp
27	10.9 – 13.8	2.9	175	M3
39	11.2 – 14.6	3.4	185	M6
19	11.2 – 14.8	3.6	230	M4
25	11.2 – 14.8	3.6	205	–
14	11.3 – 14.8	3.5	310	M5
01	11.5 – 14.8	3.3	225	M7
07	11.6 – 14.8	3.2	160	–
23	12.1 – 14.8	2.7	340	–
34	12.1 – 15.0	2.9	180	–
10	12.3 – 14.6	2.3	330	–

The periods of the light variations of the Mira type variables are estimated to be correct within 5 days and the epoch of maximum light within 10 days. As the photometric plates were only exposed at intervals of about a month, they were not appropriate for establishing light curves for short-period variables. Therefore, variables with periods shorter than 150 days were excluded from the search. Figure 1 shows the obtained distribution of faint Mira type variables as function of their periods. It should be noted that some of the variables assigned a period close to a year may in fact have a period half of that given in the Catalogue, if they happened to have another maximum that fell outside the observing season. On the other hand, stars with a period close to a year and with maxima solely outside the observing season may have been missed altogether.

There is an indication in the Catalogue that Mira type variables of spectral classes M3 and M4 are confined to stars with periods shorter than 250 days. This might, however, be a misleading conclusion due to the small sample of stars of these two classes.

This project was completed in 1973 but its publication was delayed for various reasons. A. Terzan and his colleagues at the Lyon Observatory published in 1997 (Terzan et al., 1997) their results of an ambitious search for very faint variables in a field covering 100 square degrees in the direction of the galactic centre that included our field. Their photometric plates had been obtained with the 48 inch Mount Palomar Schmidt and the 1 metre ESO Schmidt, both with a scale of 67 arcsec/mm, being far superior for this kind of work to the Uppsala-Schmidt with its scale of 120 arcsec/mm.

By comparing the equatorial coordinates for the variables in our Catalogue with those in the lists of Terzan et al. (1997 and 1982) we could identify 54 of our variables in their star lists. All the remaining 16 stars might not be new discoveries as our coordinates had been obtained with a simple unpretentious plate measuring machine of unproven accuracy. With a bit more effort, a few more stars might be identified. Some of our stars may erroneously have been classified by us as variables or assigned inaccurate coordinates, although two persons were always present when identifying the stars on the plates, estimating their magnitudes or measuring their coordinates.

Far more serious is the fact that our magnitude scale at its faint end appears more contracted than the one Terzan et al. used. Already at $R_{\rm max} = 11.5$, our stars are systematically listed half a magnitude brighter than the same stars in Terzan's 1997 list and at $R_{\rm max} = 12.5$ a whole magnitude brighter. No reason for this discrepancy is suggested.

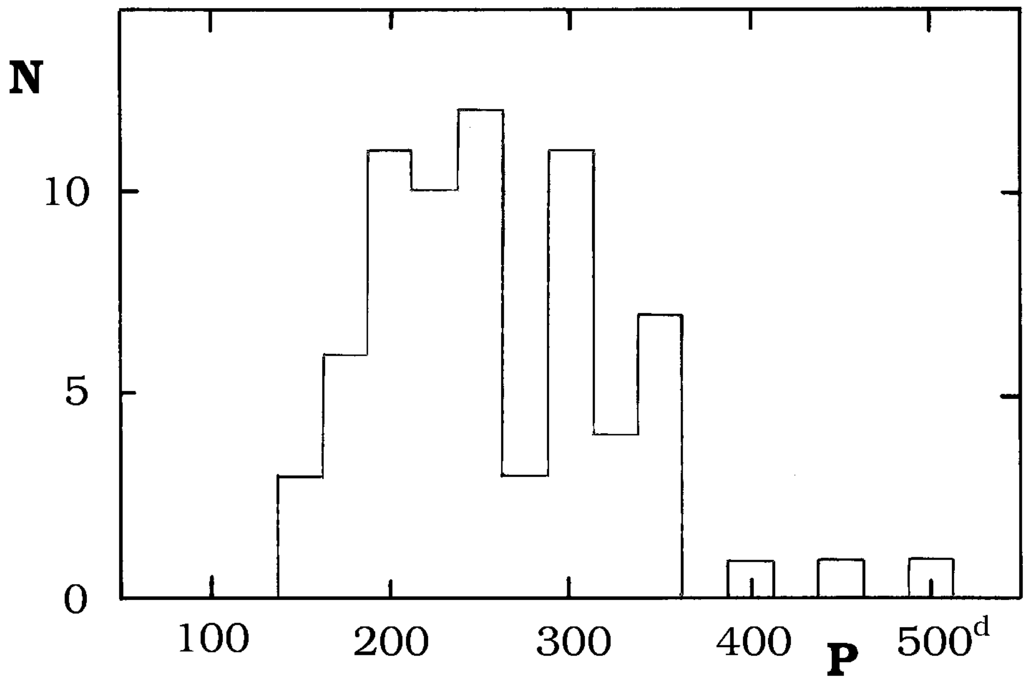

Figure 1. Observed distribution in 25 day intervals of periods of light variations of faint Mira type variables.

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Catalogue of faint Mira type variables

Column 1. Star number for stars in this Catalogue.
Column 2. Terzan star number.
Columns 3 and 4. Equatorial coordinates at the epoch 2000.0.
Columns 5 and 6. Galactic coordinates.
Column 7. Apparent red magnitude at maximum light.
Column 8. Julian date of the epoch of maximum light.
Column 9. Mean period in days of light variations.
Column 10. Spectral class at maximum light.

No	Terzan	α_{2000} (^{h} ^{m} ^{s})	δ_{2000} ($^\circ$ $'$ $''$)	l ($^\circ$)	b ($^\circ$)	R_{max} (mag)	E	P (day)	Sp
01	3689	17 11 02.4	−34 02 56	351.66	+3.30	11.5	2439700	225	M7
02	3701	17 11 15.6	−32 38 08	352.83	+4.09	12.5	2441180	285	M6
03	3703	17 11 16.4	−33 59 04	351.74	+3.30	12.2	2439675	210	–
04	3709	17 11 19.1	−32 26 31	353.00	+4.20	12.0	2440030	150	–
05	3716	17 11 27.3	−32 56 26	352.61	+3.88	12.5	2440700	395	M6
06	3721	17 11 31.8	−32 25 05	353.04	+4.17	12.5	2440090	235	–
07	3722	17 11 32.2	−32 29 18	352.98	+4.13	11.6	2440110	160	–
08		17 11 33.2	−32 12 34	353.21	+4.29	12.5	2440485	335	–
09	3729	17 11 41.8	−33 27 45	352.22	+3.53	12.6	2440690	340	M6
10		17 11 43.0	−33 28 03	352.21	+3.53	12.3	2440490	330	–
11		17 11 43.3	−33 17 36	352.36	+3.63	12.9	2440095	290	–
12		17 11 50.0	−32 34 59	352.95	+4.03	13.0	2440095	155	M7:
13	3737	17 11 51.5	−32 51 59	352.72	+3.86	11.4	2440090	260	M7
14	3739	17 11 53.0	−33 00 59	352.60	+3.76	11.3	2440380	310	M5
15		17 11 53.2	−33 19 55	352.34	+3.58	11.8	2440360	235	M6
16	3740	17 11 53.5	−32 59 53	352.62	+3.77	12.3	2439750	250	M3
17	3733	17 11 55.8	−32 58 00	352.65	+3.78	11.0	2440030	345	M5
18	3753	17 12 05.2	−32 13 47	353.26	+4.19	12.9	2440670	335	M7:
19	3754	17 12 05.9	−32 17 13	353.22	+4.15	11.2	2440690	230	M4
20		17 12 13.5	−32 18 54	353.21	+4.12	12.7	2440080	350	–
21	3761	17 12 15.1	−33 15 18	352.45	+3.56	12.7	2440505	295	–
22	3773	17 12 22.9	−34 06 53	351.77	+3.03	11.5	2439700	200	M5:
23		17 12 31.5	−32 48 49	352.84	+3.77	12.1	2440440	340	–
24	3792	17 12 40.9	−32 04 57	353.46	+4.17	11.9	2439690	225	–
25	3801	17 12 53.8	−32 14 26	353.36	+4.05	11.2	2440040	205	–
26	3805	17 13 01.2	−33 41 45	352.19	+3.17	12.2	2440380	260	M5
27	3806	17 13 03.1	−33 36 20	352.27	+3.22	10.9	2440480	175	M3
28		17 13 10.5	−32 39 23	353.05	+3.75	12.1	2439660	195	M7
29	3820	17 13 10.8	−32 49 19	352.92	+3.66	12.9	2439720	290	M7
30	3822	17 13 14.9	−32 07 32	353.49	+4.05	13.0	2440720	185	–
31	3837	17 13 23.9	−32 12 03	353.45	+3.98	13.1	2441090	350	–
32	3843	17 13 33.0	−32 56 59	352.86	+3.52	13.1	2440095	240	–
33	3849	17 13 37.6	−33 08 27	352.71	+3.39	12.7	2440690	300	–
34	3875	17 13 53.8	−32 54 11	352.94	+3.49	12.1	2440450	180	–
35	3877	17 13 56.4	−34 01 42	352.03	+2.82	12.0	2439715	215	–

No	Terzan	α_{2000} (^{h} ^{m} ^{s})	δ_{2000} ($^{\circ}$ $'$ $''$)	l ($^{\circ}$)	b ($^{\circ}$)	R_{max} (mag)	E	P (day)	Sp
36	3879	17 13 59.2	−32 27 03	353.32	+3.74	12.1	2440680	490	M7:
37	3880	17 13 59.8	−32 03 24	353.64	+3.96	12.7	2440500	300	M7
38		17 14 00.2	−32 52 09	352.98	+3.49	11.7	2439730	210	–
39	3883	17 14 03.2	−32 00 37	353.69	+3.98	11.2	2440695	185	M6
40		17 14 03.7	−32 21 59	353.40	+3.77	12.6	2439700	270	M6
41	3887	17 14 06.0	−32 04 42	353.64	+3.93	13.3	2440700	300	–
42		17 14 06.5	−32 03 33	353.65	+3.94	12.9	2440690	300	–
43	3893	17 14 09.6	−33 08 05	352.78	+3.31	12.9	2440345	280	–
44	3899	17 14 22.5	−32 27 29	353.36	+3.66	12.5	2439715	185	M3
45	3915	17 14 35.3	−33 40 40	352.39	+2.92	13.0	2440700	220	–
46	3921	17 14 38.3	−32 25 12	353.42	+3.64	12.1	2439705	210	M4:
47	3923	17 14 40.2	−32 26 08	353.42	+3.63	12.5	2440680	355	M6
48	3925	17 14 41.7	−32 09 17	353.65	+3.79	11.6	2440060	240	M6
49	3927	17 14 43.5	−32 10 23	353.64	+3.77	12.2	2439800	305	–
50	3937	17 14 48.3	−32 41 26	353.22	+3.46	12.3	2440740	230	M7
51	3943	17 14 53.3	−32 06 27	353.71	+3.78	13.2	2440695	355	–
52		17 15 15.0	−33 25 28	352.68	+2.95	12.9	2440370	200	–
53		17 15 21.8	−32 20 47	353.57	+3.56	12.3	2440400	250	M7
54	3975	17 15 22.6	−32 36 08	353.37	+3.41	12.9	2439630	295	M7
55	3977	17 15 24.3	−32 28 23	353.48	+3.48	12.3	2440030	250	M6
56	3980	17 15 25.9	−32 26 53	353.50	+3.49	12.3	2441180	240	–
57	3985	17 15 28.9	−32 14 28	353.67	+3.60	12.4	2440090	240	–
58		17 15 33.1	−32 46 34	353.25	+3.28	12.8	2440110	220	–
59	4042	17 16 30.1	−33 36 27	352.68	+2.63	13.4	2439730	305	M7
60		17 16 34.0	−32 39 04	353.47	+3.18	12.0	2440380	260	M5
61	4051	17 16 38.5	−32 40 05	353.47	+3.15	12.9	2439705	465	–
62	4060	17 16 52.3	−33 00 35	353.22	+2.92	13.1	2440485	240	–
63	1	17 17 00.5	−32 06 22	353.97	+3.42	12.2	2439660	200	–
64	3	17 17 02.9	−32 03 59	354.01	+3.43	12.2	2440040	205	M6:
65	4080	17 17 09.6	−34 15 57	352.22	+2.14	11.9	2440675	205	M5
66		17 17 16.5	−32 45 59	353.46	+2.99	12.9	2439700	195	–
67	4093	17 17 22.3	−32 17 37	353.86	+3.24	12.6	2441060	225	–
68	4118	17 17 58.4	−34 13 21	352.36	+2.03	12.2	2440370	250	M6
69	4131	17 18 05.3	−32 47 43	353.54	+2.83	12.2	2439700	180	–
70	4145	17 18 33.9	−32 07 44	354.14	+3.13	12.9	2440090	335	–