Abstract:

A set of 64 simultaneous optical and near-infrared photometric observations of 17 late-type giants in the Johnson UBVRIJHK system obtained in 1995-1999 is presented for the first time.

Keywords: Astronomy | photometry | Late-type giant stars

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SIMULTANEOUS MULTICOLOUR PHOTOMETRY OF LATE-TYPE GIANT STARS

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Late-type giant stars are post-main-sequence objects undergoing a relatively fast evolution of their interior structure (e.g., dredge-ups, thermal pulses) that causes multi-wavelength variations of their brightness. Simultaneous photometric observations in wide wavelength ranges important to study the behaviour of the objects are still rare. Here we report the results of an observing programme that included 17 objects (7 carbon stars, 7 M–type giants, and 3 Mira variables) which have never been published, except for a short presentation at a carbon star conference (Miroshnichenko et al., 2000). The programme objects were selected from a list of IRAS sources studied by Ivezić & Elitzur (1995).

The $UBVRIJHK$ observations in the Johnson photometric system were obtained between August 1995 and March 1999 at a 1–meter telescope of the Tien-Shan Observatory of the Fesenkov Astrophysical Institute (Kazakhstan) with a two–channel photometer–polarimeter of the Pulkovo Observatory (Bergner et al., 1988). The results are presented in Table 1. The typical duration of an eight filter observation was $\sim$20 minutes. Each object was observed with one $UBVRI$ and one JHK standard star. The photometric data of standard stars shown in Table 2 was taken from Johnson et al. (1966) and Kornilov et al. (1991). A few missing colour-indices (e.g., $R-I$ and $J-H$) were derived by us. Observations of multiple standard stars every night ensured accurate atmospheric extinction determination and control of the detector's stability.

Transformations between the instrumental and standard photometric systems were derived by observing groups of standard stars every several months and found stable over long time (years). They depend on the spectral sensitivity of the detectors, that changed from time to time. The transformations for the detectors used in 1980's were published in Bergner et al. (1988). Those derived during the time of reported observations are as follows: $\Delta(U-B) = (0.958 \pm 0.008)\,\Delta(u-b)$, $\Delta(B-V) = (0.983 \pm 0.007)\,\Delta(b-v)$, $\Delta V = \Delta v + (0.077 \pm 0.012)\,\Delta(b-v)$, $\Delta R = \Delta r - (0.47 \pm 0.02)\,\Delta(r-i)$, $\Delta(R-I) = (0.90 \pm 0.02)\,\Delta(r-i)$, $\Delta(J-H) = (0.82 \pm 0.02)\,\Delta(j-h)$, $\Delta(H-K) = (0.99 \pm 0.02)\,\Delta(h-k)$, and $\Delta K = \Delta k + (0.02 \pm 0.02)\,\Delta(h-k)$. Capital letters refer to the standard system, and lower case letters refer to the instrumental magnitudes and colour-indices free of atmospheric extinction. The Δ notation refers to the magnitude and colour-index differences between variables and comparison stars.

The photometer was designed to use two single-element detectors (a GaAs photomultiplier for the optical range and a PbS photoresistor for the near-IR range) simultaneously to collect the star light and subtract the sky background. It was ideal for observing objects with a very red continuum or strong IR excesses. Numerous results on a wide variety of objects ranging from pre-main-sequence stars to those at advanced evolutionary stages obtained with this device in 1984–2002 have been published in many papers. Some examples include multicolour photometry of VV Cep stars (Miroshnichenko & Ivanov, 1993), objects with the B[e] phenomenon (Bergner et al., 1995), the newly discovered Mira V1137 Aql (Miroshnichenko, 2001), the LBV candidate MWC 930 (Miroshnichenko et al., 2005), and the Be binary δ Scorpii (Carciofi et al., 2006).

The intent of this paper is to report the data which can be useful for constructing more detailed light curves of the objects, analyzing their spectral energy distributions, modeling their dusty envelopes, etc. These data may be important because all the objects are very bright in the near-IR region and therefore saturate most modern detectors, including those of actively used all-sky surveys (2MASS, DENIS, etc.).

Table 1. Photometric data

Star	JD−2400000	$U-B$	$B-V$	V	$V-R$	$R-I$	J	H	K
EP Aqr	49939.28	0.65	1.68	6.48	3.24	1.82	−0.28	−1.06	−1.44
EP Aqr	49943.34	0.59	1.76	6.53	3.07	1.99	−0.29	−1.05	−1.44
R Cnc	50093.35	−0.29	1.80	7.93	3.56	2.33	0.37	−0.49	−0.94
R Cnc	50105.32	−0.31	1.84	8.22	3.48	2.36	0.39	−0.44	−0.87
R Cnc	50415.48	−0.03	1.78	7.98	3.39	2.25	0.69	−0.04	−0.51
R Cnc	50416.48	0.00	1.74	8.03	3.37	2.34	0.68	−0.05	−0.47
R Cnc	50417.47	0.00	1.75	7.99	3.32	2.29	0.58	−0.15	−0.52
R Cnc	50419.45	0.01	1.74	8.04	3.36	2.18	0.68	−0.06	−0.51
R Cnc	50422.43	0.00	1.77	8.07	3.29	2.12	0.66	−0.10	−0.52
R Cnc	50423.44	−0.07	1.72	8.15	3.46	2.29	0.65	−0.08	−0.60
R Cnc	50424.44	−0.04	1.79	8.09	3.37	2.27	0.65	−0.15	−0.53
R Cnc	50429.43	−0.10	1.80	8.22	3.49	2.40	0.58	−0.21	−0.62
R Cnc	50433.40	−0.11	1.75	8.32	3.41	2.29	0.67	−0.01	−0.53
R Cnc	50439.39	−0.13	1.76	8.44	3.45	2.28	0.58	−0.18	−0.61
R Cnc	50538.16	−0.08	1.74	10.99	4.47	3.13	1.03	0.20	−0.47
R Cnc	51153.41	−0.11	1.64	7.74	3.56	2.24	–	–	–
Y CVn	50101.51	5.32	3.28	5.50	2.04	1.35	1.17	0.14	−0.61
Y CVn	50538.39	–	3.25	5.15	1.95	1.28	0.87	−0.05	−0.66
Y CVn	50540.34	–	3.20	5.30	1.95	1.27	0.90	−0.02	−0.70
V CVn	50540.38	1.13	1.81	7.97	2.64	1.86	2.21	1.41	1.10
S Cep	49940.44	–	6.17[a]	9.44[b]	3.16[b]	1.75	2.54	1.23	−0.01
S Cep	49944.36	–	5.71	9.34	3.10	1.68	2.51	1.24	−0.04
S Cep	50342.29	–	–	–	–	–	2.99	1.83	0.64
V CrB	50540.41	–	3.77	7.85	1.89	1.25	3.29	2.32	1.47
V CrB	51246.45	–	4.64	8.76	2.22	1.29	3.67	2.64	1.69

Table 1. Photometric data (continued)

Star	JD−2400000	$U-B$	$B-V$	V	$V-R$	$V-I$	J	H	K
U Cyg	50428.03	–	5.26	8.87	2.83	1.61	2.81	2.04	1.26
U Cyg	50433.03	–	5.29	8.58	2.66	1.69	2.75	1.94	1.20
RY Dra	50101.54	–	3.64	6.94	2.11	1.60	2.01	1.29	0.46
RY Dra	50107.46	4.42	3.72	6.92	2.17	1.43	2.00	1.28	0.44
RY Dra	50538.36	4.81	4.00	6.51	2.09	1.30	1.80	1.06	0.23
CS Dra	50093.49	0.49	2.02	10.73	3.80	2.77	2.09	1.18	0.72
CS Dra	50538.27	0.70	1.99	10.52	3.61	2.47	2.13	1.12	0.73
CS Dra	50540.31	0.28	1.75	10.75	3.46	2.47	2.36	1.45	0.92
RV Peg	50673.36	−0.03	1.97	11.72	4.19	2.58	3.03	2.30	1.86
RV Peg	50674.37	−0.09	1.92	11.71	4.15	2.54	3.06	2.32	1.82
RV Peg	50677.35	–	1.87	11.74	4.28	2.58	3.05	2.22	1.83
RZ Peg	50424.03	–	4.29	9.78	2.27	1.40	4.36	3.45	2.88
RZ Peg	50427.03	–	4.52[c]	9.63	2.13	1.39	4.40	3.44	2.82
RZ Peg	50429.04	–	–	–	–	–	4.40	3.47	2.89
RZ Peg	50439.03	–	4.17	9.34	2.16	1.28	4.36	3.53	2.83
TW Peg	49940.39	1.24	1.68	7.24	2.89	2.29	0.61	−0.13	−0.51
TW Peg	49942.39	1.23	1.76	7.16	2.85	2.41	0.63	−0.12	−0.52
TW Peg	49944.32	1.24	1.48	7.35	2.94	2.17	0.58	−0.12	–
S Per	50093.14	–	2.73	11.11	4.07	2.58	2.87	1.87	1.24
S Per	50353.45	–	2.68	11.90	3.99	2.17	3.46	2.42	1.65
R UMa	50093.43	0.74	1.29	7.99	2.58	2.19	2.50	1.79	1.30
R UMa	50097.39	0.69	1.32	7.93	2.62	2.10	2.43	1.69	1.27
R UMa	50107.44	0.58	1.27	8.19	2.74	2.27	2.34	1.62	1.15
R UMa	50538.25	0.46	1.92	11.97	4.13	2.71	2.70	1.89	1.44
R UMa	50540.27	0.26	2.08	11.86	4.03	2.71	2.62	1.94	1.45
R UMa	51246.29	0.61	1.57	10.74	3.74	2.52	3.06	2.34	1.76
RZ UMa	50419.48	0.76	1.80	9.46	3.36	2.16	2.09	1.42	1.09
RZ UMa	50422.48	0.68	1.98	9.38	3.08	1.98	2.07	1.35	1.03
RZ UMa	50423.48	0.76	1.78	9.54	3.45	2.24	2.11	1.32	1.00
RZ UMa	51160.43	0.88	1.82	8.89	3.15	2.12	–	–	–
VY UMa	50093.46	4.63	2.59	6.06	1.62	1.34	2.15	1.18	0.64
VY UMa	50097.41	4.56	2.61	6.03	1.66	1.25	2.11	1.19	0.66
VY UMa	50101.46	4.65	2.56	6.08	1.64	1.30	2.13	1.15	0.62
VY UMa	50107.42	4.83	2.58	6.11	1.64	1.32	2.12	1.17	0.64
VY UMa	50538.22	4.79	2.60	6.14	1.65	1.24	1.98	1.12	0.64
VY UMa	50540.29	4.96	2.69	6.08	1.67	1.25	1.92	1.04	0.52
VY UMa	51246.29	4.81	2.63	6.15	1.68	1.32	2.12	1.14	0.65
AZ UMa	50097.48	0.93	1.72	8.72	3.12	2.00	2.09	1.23	0.84
AZ UMa	50538.30	0.90	1.52	8.64	3.04	2.02	2.01	1.20	0.82

The typical uncertainties (including those of transformation from the instrumental to the standard photometric system) are as follows: $0\overset{m}{.}02$ in V, $B-V$, J, H, and K; $0\overset{m}{.}04$ in $V-R$ and $R-I$; $0\overset{m}{.}02$ in $U-B$ for $U \leq 12\overset{m}{.}5$; $0\overset{m}{.}04$ in $U-B$ for fainter U–magnitudes.
Larger uncertainties for specific cases are marked with letters: [a] $0\overset{m}{.}08$, [b] $0\overset{m}{.}05$, [c] $0\overset{m}{.}04$.

Table 2. Data on comparison stars

Var.	Vis. comp	$U-B$	$B-V$	V	$V-R$	$R-I$	IR comp	J	H	K
EP Aqr	HD 207435	0.83	1.01	6.67	0.75	0.32	BS 8414	1.47	1.09	0.97
R Cnc	HD 68425	1.75	1.55	7.65	1.02	0.90	BS 3249	1.08	0.28	0.15
V CVn	HD 116172	0.47	0.93	6.98	0.71	0.47	BS 4997	3.12	2.76	2.66
Y CVn	HD 110835	1.52	1.37	6.96	0.71	0.70	BS 4785	3.23	2.88	2.84
S Cep	HD 209111	1.57	1.54	6.53	1.83	1.60	BS 8347	2.62	1.90	1.70
V CrB	HD 140086	1.53	1.56	6.92	1.18	0.90	BS 5901	3.09	2.58	2.49
U Cyg	HD 194193	1.98	1.65	5.94	1.28	0.85	BS 7796	1.16	0.87	0.75
RY Dra	HD 112640	1.65	1.45	6.55	1.00	0.65	BS 4928	3.08	2.47	2.35
CS Dra	HD 97619	1.46	1.34	6.90	0.96	0.65	BS 4301	0.05	-0.55	-0.65
TW Peg	HD 212750	1.06	1.14	7.13	0.86	0.54	BS 8430	2.98	2.78	2.67
S Per	HD 13403	0.11	0.66	7.02	0.55	0.24	BS 799	3.34	3.07	2.98
RZ UMa	HD 66823	1.94	1.59	7.37	1.23	0.95	BS 3323	1.98	1.49	1.44
AZ UMa	HD 101853	0.73	0.97	6.73	1.02	0.90	BS 4518	1.72	1.08	0.95

Comparison stars for R UMa and VY UMa were the same as for CS Dra.
Comparison stars for RZ Peg and RV Peg were the same as for TW Peg .

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