J. Astrophys. Astr. (1982) **3,** 451–463

Near Infrared Observations of some of the IRC Sources*

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Received 1982 April 12; accepted 1982 September 29

Abstract. Using an Infrared photometer with InSb photovoltaic detector at the 182cm Copernicus telescope of the Asiago Observatory, Italy, we have measured the *JHKL' M* magnitudes of 12 IRC sources 7 of which are very late type stars with $[I_{\mathrm{CIT}} - K]$ greater than 5 magnitudes. These data have been fitted to blackbody distributions to obtain their effective temperatures. The present data, in combination with other available photometric data at longer wavelengths seems to indicate excess emission at 11 μm from sources 10066, 10510 and 10234, and at 19·8 μm from source 20052. The source 60098 shows extreme infrared colours.

Key words: IRCCIT sources–broadband infrared photometry–infrared excess

1. Introduction

We have measured the *JHKL'M* magnitudes of 12starsfromthe IRC-CIT two-micron sky survey (Neugebauer and Leighton 1969). Seven of these have $[I_{\mathrm{CIT}} - K] > 5$ magnitudes. The photometric data on these extremely red objects in the near-infrared bands are rather scanty. Our interest was to determine the effective temperatures of these sources corresponding to their photometric magnitudes and also to use these photometric data with similar data at longer wavelengths from the AFGL Sky Survey of Price and Walker (1976), from Dyck, Lockwood and Capps (1974) and from Strecker and Ney (1974) to derive information on infrared excess (if any) from these sources.

*Work carried out when the first author was a guest scientist at Max Planck-Institut für Extraterrestrische Physik, *Garching* FRG.

2. Observations

We used an Infrared photometer with InSb photovoltaic detector from SBRC Inc., cooled by liquid nitrogen at the Cassegrain focus of the 182-cm, f/9 Copernicus telescope of the Asiago Observatory at Italy. The preamplifier used a cooled FET mounted on the cold work surface of the dewar. The NEP of the detector was 1×10^{-15} W $(\mathrm{Hz})^{-1/2}$ at 5 μm. Interference filters from Optical Coating Laboratories Inc., were used to define the *JHKL'M* photometric bands. Our L' and M bands correspond to effective wavelengths of 3·85 and 4·70 μm, respectively. The observations were carried out on the nights of 1980 November 1923, using a field of view of 10 arcsec. The beam was chopped in declination at 20 Hz and the throw was set at 18 arcsec. α Ceti, α CMa, α Tau, β And and β CMa were used for calibration of the infrared fluxes. The fluxes of these stars in our photometric bands were obtained from the data of Strecker, Erickson and Witteborn (1979). To keep the corrections due to differences in the air mass corresponding to the observation of the calibration star and the programme stars small, the observations were all carried out at an air mass of 1·2 ± 0·2.

3. Nature of the programme sources

We describe briefly in this section the nature of the programme sources (listed in Table 1) before we proceed to discuss analysis of their photometric data in Section 4, as the nature of these sources has a close bearing on the method chosen for the analysis of the data.

3.1 *Spectral Type and Variability*

3.1.1 *Sources with* $[I_{\mathrm{CIT}} - K] > 5$

Sources 10061,10066 and 10234 are Mira variables of Type M with periods ~ 350 days and spectral types ranging from M 5·0e–M 9·0e as a function of their phase. 10061 appears to be variable in the K band (Neugebauer and Leighton 1969). Source 10510 is identified with the variable SVS 102147 in the AFGL Sky Survey (Price and Walker 1976). The 4·2μm and 11·00 μm observations of 10510 from this survey seem to indicate slight variability even at these wavelengths. The CIT Sky Survey of Neugebauer and Leighton (1969) showed it to be variable in the K band. Source 20052 is classified as a star of spectral type M 8·1 (Dyck, Lockwood and Capps 1974). No information is available on the spectral type of the sources 10120 and 30091. All these sources have galactic latitude $|b^{\mathrm{II}}| > 10°$ save 10120 which is in the galactic plane with $b^{\mathrm{II}} = 0°.6$.

3.1.2 *Sources with* $[I_{\mathrm{CIT}} - K] < 5$

Of these five sources only 60098 is a variable. It is identified as V499 Cas by Price and Walker (1976). No information is available on its spectral type. The spectral types of the other four sources are known.

Table 1. Infrared magnitudes of programme sources.

IRC No. GL No.	Present observations	IRC catalogue	GL catalogue	Strecker and Ney	Spectral type and luminosity class
	[J]	[I_{CIT}]	[4·2]	[2·3]	
	[H]	[I_J]	[11·0]	[3·5]	
	[K]	[K]	[19·8]	[4·8]	
	[L']	[$I_{CIT}-K$]		[8·6]	
	[M]			[10·7]	
(1)	(2)	(3)	(4)	(5)	(6)
10061	4·04	8·47 ± 0·30			M5·0e–M8·0e[a]
	3·12	6·92 ± 0·34			M
	2·66	3·04 ± 0·11$_V$			
	1·9	5·43 ± 0·32			
	2·0				
10066	3·04	7·10 ± 0·14	0·6 ± 0·3		M6·5e –M8·5e[a]
608	2·11	5·49 ± 0·16	−1·4 ± 0·4		M
	1·50	1·45 ± 0·06			
	0·6	5·65 ± 0·15			
	0·3				
10120	4·08	7·83 ± 0·15		2·6 ± 0·1	
	3·00	6·35 ± 0·17		2·2 ± 0·1	
	2·55	2·69 ± 0·06		2·2 ± 0·1	
	2·0	5·14 ± 0·16		(1·3)	
	2·4			(1·4)	
10234	3·72	8·35 ± 0·24	1·0 ± 0·3		M7·5e–M9·0e[a]
1441	2·74	6·71 ± 0·26	−0·9 ± 0·4		M
	2·29	2·59 ± 0·08			
	1·2	5·76 ± 0·25			
	1·3				
10510	2·76	8·15 ± 0·75	1·0 ± 0·3		M7[b]
2851	1·70	6·39 ± 0·75	−1·3 ± 0·4		
	1·11	1·92 ± 0·06$_V$			
	0·3	6·23 ± 0·75			
20052	2·75	6·68 ± 0·09	0·8 ± 0·3	1·3 ± 0·1	M8·1[c]
414	1·67	5·18 ± 0·16		0·9 ± 0·1	
	1·25	1·44 ± 0·09	−3·1 ± 0·4	0·9 ± 0·1	
	0·9	5·24 ± 0·13		(0·8)	
	0·8			−0·4 ± 0·2	
30091	3·59	6·99 ± 0·13			
	2·39	5·52 ± 0·15			
	1·77	1·86 ± 0·06			
	1·3	5·13 ± 0·14			
30180	3·83	5·67 ± 0·09	1·4 ± 0·3		Mb[d]
4071	2·76	4·62 ± 0·13			
	2·72	2·18 ± 0·07			
	2·4	3·49 ± 0·11			
	2·2				

Table 1. Continued.

IRC No. GL No. (1)	Present observations [J] [H] [K] [L'] [M] (2)	IRC catalogue [I_{CIT}] [I_J] [K] [$I_{CIT}-K$] (3)	GL catalogue [4·2] [11·0] [19·8] (4)	Strecker and Ney [2·3] [3·5] [4·8] [8·6] [10·7] (5)	Spectral type and luminosity class (6)
50060	1·95	3·37 ± 0·05	0·8 ± 0·3		K4 III[d]
4022	1·26	2·65 ± 0·18			
	1·03	1·13 ± 0·05			
	0·8	2·24 ± 0·07			
	0·6				
60098	2·47	7·16 ± 0·11	1·8 ± 0·5		
4022	2·97	5·84 ± 0·15			
	2·50	2·63 ± 0·07			
	2·1	4·53 ± 0·13			
	2·8				
60133	2·42	5·24 ± 0·06	1·2 ± 0·3		M2[d]
531	1·75	4·14 ± 0·10			
	1·45	1·56 ± 0·06			
	1·3	3·68 ± 0·08			
	1·7				
70073	3·79	5·11 ± 0·07	1·6 ± 0·3		K0[d]
4067	2·94	4·34 ± 0·14			
	2·82	2·67 ± 0·09			
	2·7	2·44 ± 0·11			
	3·2				

Notes:
1. All the IRC sources referred to in this study are positive declination objects from the CIT-IRC Catalogue of Neugebauer and Leighton (1969).
2. Spectral types:
   [a]Lockwood (1972).
   [b]Wilson and Barett (1972).
   [c]Dyck, Lockwood and Capps (1974).
   [d]Neugebauer and Leighton. (1969).
3. Figures in parenthesis indicate 3σ upper limits from Strecker and Ney (1974).
4. Letter V, with the colour in a particular band from IRCCIT Survey, indicates variability in that band (Neugebauer and Leighton 1969).

3.2 *Luminosity Class of the Sources*

The Mira variables are late-type giants. The observed $JHKL'$ M magnitudes of the other sources (whose spectral type is known) are untenably high to arise from main-sequence stars. They are likely to be giants or supergiants.

3.3 *Distance to the Sources*

The distances to these sources are not known. The knowledge of their spectral types combined with the constraint on their luminosity class, however, enables us to set upper limits to their distances from the solar neighbourhood. They are in general within a few kiloparsecs from the Sun.

4. Analysis of data and results

In Table 1 are presented the IRC number of the source and GL number (where such Identification exists), photometric data from (i) the present observation, (ii) the IRC Catalogue of Neugebauer and Leighton (1969), along with I_Js obtained from the colour transformation discussed below, (iii) the GL Catalogue of Price and Walker (1976), (iv) Strecker and Ney (1974), and spectral type. Errors on the *J*, *H* and *K* magnitudes from this observation are $\lesssim \pm 0{\cdot}05$ and on L' and *M* magnitudes $\lesssim \pm 0{\cdot}2$.

The I_{CIT} magnitude of the CIT survey (Neugebauer and Leighton 1969) is different from the I_J magnitude of Johnson (1966), although the *K* magnitude of the CIT survey is the same as that of Johnson. We have derived the colour transformation relation

$$[I_J - K] = 0{\cdot}74\ [I_{CIT} - K] - 0{\cdot}14 \qquad (1)$$

from the data presented in Fig. 8 of Neugebauer and Leighton (1969) and used it to determine the I_J's corresponding to the I_{CIT}'s of Neugebauer and Leighton (1969).

IRC stars with $[I_{CIT} - K] > 5$, are in general cool giant stars. Their atomspheres are extended and contain molecules. Models of atmospheres of cool stars have been published by Johnson (1974). For a realistic comparison of these model predictions with observations, one needs photometric data with a resolution of 2 per cent or better in the 1–5 μm region (obtained above most of the earth's atomsphere). As our data is limited to observations from ground in the five broad photometric bands *JHKL'M*, we have not tried to compare them with predictions of model atmospheres from Johnson (1974).

We have fitted the photometric data in the *JHKL'M* bands (obtained at the same epoch) to blackbody distributions using effective temperature and interstellar extinction (which is a function of the distance to the sources) as parameters.

The interstellar extinction A_λ at wavelength λ in the direction of the source was estimated using the relation

$$A_\lambda(r) = a_{0\lambda}\, z_0 \operatorname{cosec} |b|\, [1 - \exp(-r \sin |b| / z_0)]. \qquad (2)$$

Here, $a_{0\lambda}$ is the interstellar extinction coefficient in the galactic plane at wavelength λ, z_0 is the scale height of the obscuring matter, *r* is the distance to the source from the Sun (both in parsecs) and *b* is the galactic latitude. We assumed $z_0 = 140$ pc and $\alpha_{0\lambda} = 0{\cdot}8 \times 10^{-3}$ mag pc^{-1} in the *V* band in accordance with Allen (1973). We used the theoretical curve No. 15 of Van de Hulst (quoted by Johnson 1968) to evaluate $\alpha_{0\lambda}$ as a function of λ. It should be noted that the value assumed for $a_{0\lambda}$ is a statistical mean value for extinction in the galactic plane and is likely to differ from this value as a function of direction.

The temperatures obtained from this fitting procedure are the best fit values within ± 50 K for these sources.

In Table 2 are listed the source number, their celestial and galactic coordinates, the variable name and other relevant parameters and the best fit values of distance and temperature. These fits appear extremely insensitive to distance.

Table 2. Temperature from fits of blackbody distributions to photometric data obtained in the present investigation.

IRC No. GL No. (1)	RA. (1950) l^{II} (2)	Dec. (1950) b^{II} (2)	Variable name Period (d) ⟨Max⟩ ⟨Min⟩ (3)	Parameters obtained from blackbody fits to data Distance (pc) (4)	 Temperature (°K) (4)
10061	$04^h\ 26^m\ 29^s$	+09° 50′·6	S Tau[a]	600	2575
	185°·6	−22°·5	373·3		
			10·2		
			15·3		
10066	04 35 30	+08 13·6	RX Tau[b]	100	2300
608	188·5	−24·7	335·1		
			9·6		
			14·0		
10120	06 21 24	+14 15·2		1900	2700
	197·2	0·6			
10234	10 50 58	+13 59·1	W Leo[b]	200	2475
1441	233·0	59·4	385·5		
			9·8		
			14·2		
10510	22 04 52	+11 39·3	SVS 102147	25	2225
2851	71·9	−34·3			
20052	02 58 43	+21 36·1		200	2450
414	158·9	−31·8			
30091	04 34 28	+32 31·5		25	2075
	168·4	− 9·6			
30180	07 17 04	+31 27·1		25	2975
4071	186·9	19·4			
50060	02 22 15	+50 30·8		25	3350
4022	137·8	−9·4			
60098	02 47 00	+60 32·8	V499 Cas[b]	25	5775
4026	137·0	1·2			
			13·4†		
			14·7†		
60133	03 51 43	+57 31·6		1900	3850
	145·6	3·2			
70073	07 00 14	+70 48·9		550	3600
	144·6	26·7			

Notes:

⟨Max⟩ and ⟨Min⟩ in column 3 correspond to mean maximum and minimum magnitudes in the visual band as given in

[a]Kukarkin *et al.* (1969),

[b]Kukarkin *et al.* (1974).

†maximum and minimum photographic magnitudes as given in Kukarkin *et al.* (1974).

Photometric data from this study, along with data from other observers (corrected for extinction on the basis of the best fit distances) are presented in Fig. 1 for sources

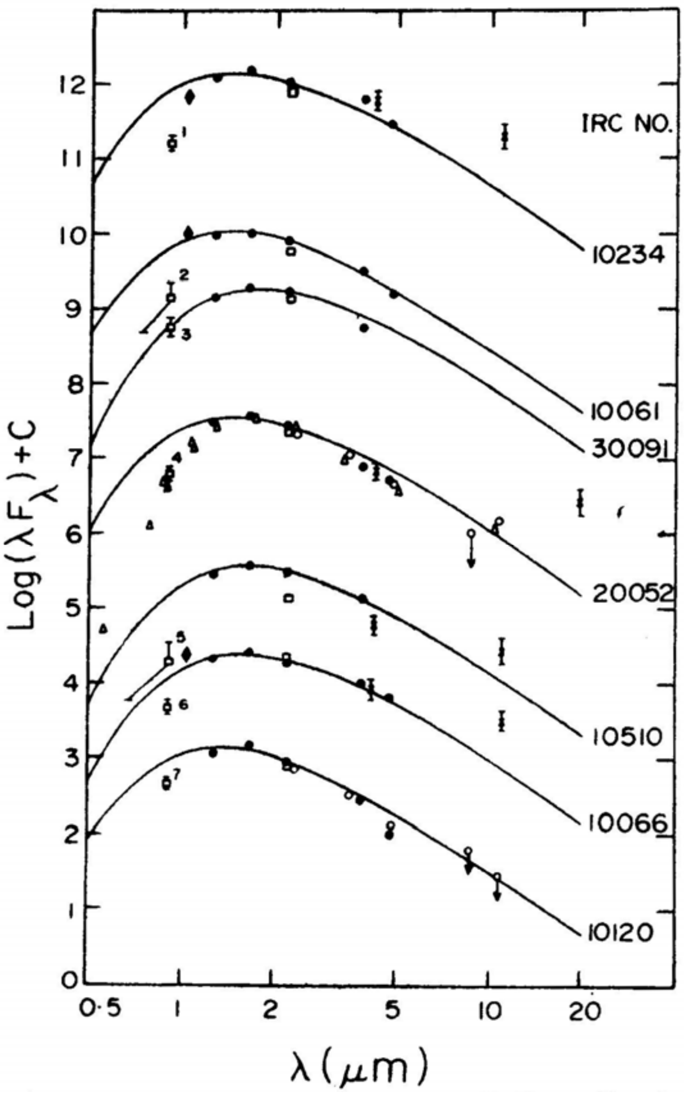

Figure 1. Flux distributions (W cm^{-2}) of programme sources with $[I_{CIT} - K] > 5$. The constant *C*, added to the ordinate to separate the spectra of the sources has the values 17, 18, 19, 21, 23, 24 and 26 for the sources 10120, 10066, 10510, 20052, 30091, 10061 and 10234 respectively.

- ● Present observations.
- □ at 0·9 μm (obtained from transformation of I_{CIT} to I_J) and 2·2 mm from Neugebauer and Leighton (1969). The numbers 1, 2...7, on the 0·9 μm data points refer to sources 10234, 10061, 30091, 20052, 10510, 10066, and 10120 respectively.
- × at 4·2, 11·0 and 19·8 μm from the AFGL Sky Survey (Price and Walker 1976).
- ○ at 2·3, 3·5, 4·8, 8·6 and 10·7 μm from Strecker and Ney (1974).
- Δ at 0·55, 0·78, 0·87, 0·88, 1·04, 1·05, 1·25, 1·65, 2·2, 3·4, 5·0 and 10·2 μm from Dyck, Lockwood and Capps (1974).
- ϕ at 1·035 μm are from the narrow band photometric data (Lockwood 1972) of the Mira variable sources for the phase corresponding to the time of our observation. The line through the data points of each source is the blackbody fit to the data. The flux predicted by the blackbody distribution at 2·2 μm has been normalised in each case to the observational data at that wave length. All the data points have been corrected for extinction as discussed in the text.

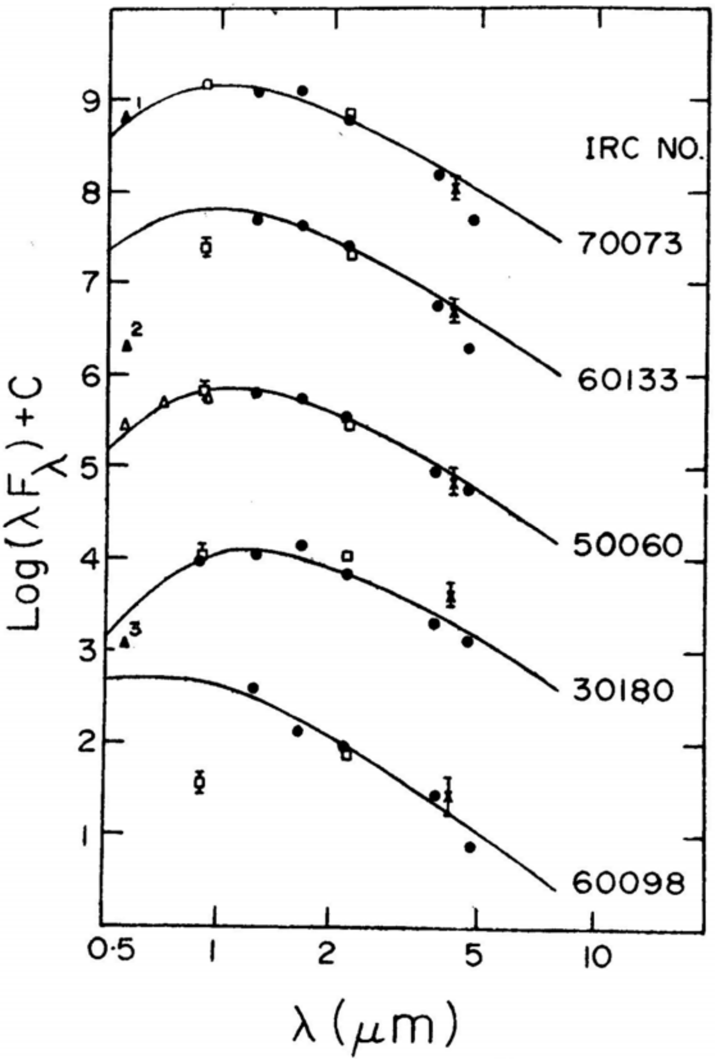

Figure 2. Flux distributions (W cm^{-2}) of programme sources with [I_{CIT} – K] < 5. The constant C (referred to in caption to Fig. 1) has the values 16, 18, 19, 21 and 23 for the sources 60098, 30180, 50060, 60133 and 70073 respectively. The data points Δ refer to 0·55, 0·70 and 0·90 μm magnitudes of IRC 50060 (BS 699) from Johnson *et al.* (1966). The symbols $▲^1$, $▲^2$, and $▲^3$ refer to the data points derived from the V magnitudes quoted by Neugebauer and Leighton (1969), for the sources 70073, 60133 and 30180, respectively. The symbols ●, □ and × along with the rest of the details are.the same as in Fig. 1.

with [I_{CIT} – K] > 5 and in Fig. 2 for sources with [I_{CIT} – K] < 5. The solid lines through the data points are the best fit blackbody distributions to the observational data from this work only. Data from other observers were not included for effecting blackbody fits, as some of the sources of this study are Mira type variables and their spectral types and magnitudes, depend sensitively on their phases at the epoch of observation.

It is seen from Fig. 1 that the observed photometric magnitudes, in the 1·25–4·7 μrn range are in. general well accounted for by blackbody distributions. A slight excess of emission is observed at 11·0 μm from sources 10066,10510 and 10234. However, these 3 sources are Mira variables. As the data under comparison are from different authors obtained at different epochs using different techniques, one cannot exclude the possibility that the observed excess over the blackbody fits to the present data is not due to either time variation of these sources or systematic differences in the observation techniques. Excess emission from source 20052 is observed at 19·8 μm without any corresponding excess at 11·0 μm. It is a late-type M giant but not a Mira variable. The lack of excess at 11·0 μm is rather intriguing.

The flux at 0·9 μm (I_J, or I band of Johnson) for the variable as well as the nonvariable sources is generally lower than the blackbody distribution except in the case of source 30091. The mean visual flux (corrected for interstellar extinction) at the maximum brightness of the Mira variable sources is also found to be 1·3 ±0·1 mag fainter than the flux predicted by the blackbody fit to their infrared photometric data. These differences owe their origin to the line and band absorption that dominates the visual spectrum of late-type giants and which departs significantly from a blackbody curve.

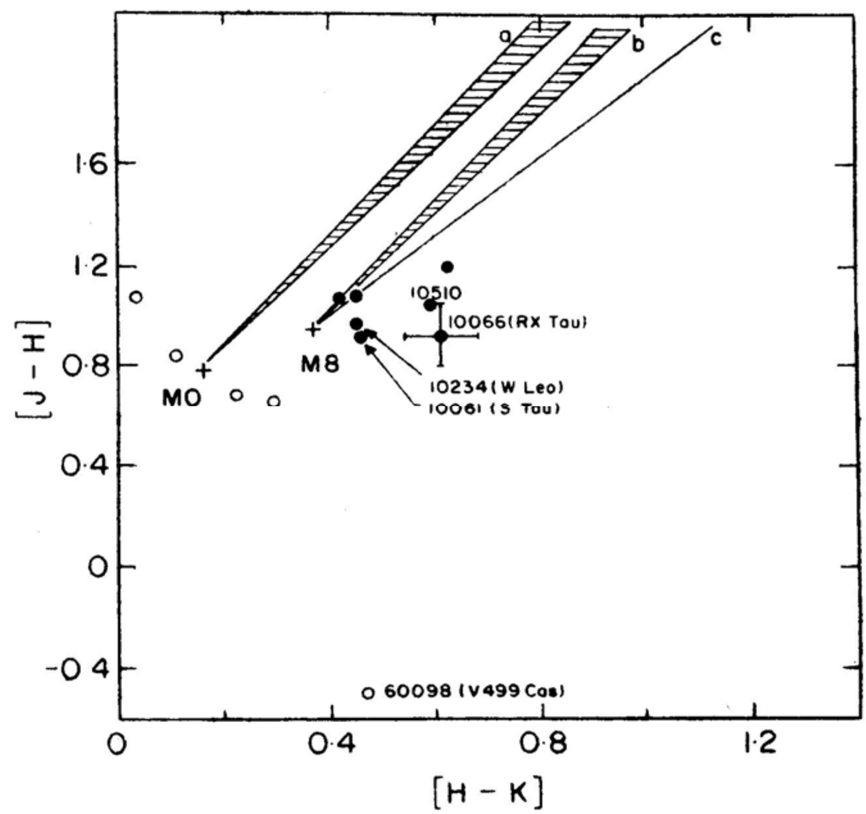

Figure 3. [H – K] versus [J – H] colour-colour diagram. The filled points and the open circles refer to sources for which [I_{CIT} – K] is greater than 5 and less than 5 respectively. The hatched, regions 'a' and 'b' are the interstellar reddening trajectories (for M0 and M8 giants) with slope $E(J-H)/E(H-K)$ = 2·09 ± 0·10 (Jones and Hyland 1980). Line 'c' is the reddening line with slope $E(J-H)/E(H-K)$ = 1·6, from Van de Hulst (Tapia 1981) for M8 giants. The error bars shown for IRC 10066 indicates the typical errors on the data points.

4.1 *Colour-Colour Diagrams*

A colour-colour plot of [*J* – *H*] versus [*H* – *K*] for the programme sources is presented in Fig. 3. The value for the colour excess ratio *E*(*J* – *H*)/*E*(*H* – *K*) appears to be highly uncertain. The present situation in this regard is detailed below.

Becklin *et al.* (1978) obtain a value of 1.50 ± 0·10 for galactic centre objects. Elias (1978a) obtains a value of 1·56 ± 0·05 for field stars in Taurus dark cloud and Elias (1978b) obtains a value of 1·60 ± 0·04 for objects in Ophiuchus dark cloud. Jones and Hyland (1980) obtain a value of 2·09 ± 0.10 for some selected group of objects covering a wide range of colour values extending up to 4·81 in [*J* – *H*] and 2·18 in [*H* – *K*]. Jones *et al.* (1980) obtain a value of 2·12 ± 0.04 for objects in Coalsack.

Frogel *et al.* (1978) adopt for giants of spectral type MO and M8, mean values of 0·74 and 0·89 for the [*J* – *H*] colour and 0·16 and 0·37 for the [*H* – *K]* colour, respectively. Their *J* band is different from that of Johnson. On transformation to the Johnson's system these result in (*J* – *H*) values of 0·81 and 0·97 for MO and M8, respectively. The hatched regions (a) and (b) in Fig. 3 are the interstellar reddening trajectories corresponding to *E*(*J* – *H*)/*E*(*H* – *K*) value from Jones and Hyland (1980) for MO and M8 type giants, respectively. The line (c)corresponds to *E*(*J* – *H*)/*E*(*H* – *K*) 1-6 from curve No. 15 of Van de Hulst, (quoted by Tapia 1981). The [*J* – *H*] and [*H* – *K*] values of our programme stars are limited to a narrow range of ~1·2 and ~1·6 respectively. The points corresponding to sources 10066, 10510 and 60098 fall outside the reddening line. Sources 10066 and 10510 seem to have excess emission at 11·0 μm. It is likely that their excess in [*H* – *K*] relative to [*J* – *H*] is due to infrared emission that might be arising from circumstellar material around them.

The blackbody fit to the *JHKL'M* photometric data of IRC 60098 (V 499 Cas) yields a temperature of 5775 K, which corresponds to that of a giant star of spectral type GO – G5. The observed 0·9 [cm flux is lower than that predicted by its effective temperature by about 3 magnitudes. The amplitude of its variability in the photographic band is ~1·3 mag and is much less than that of Mira-type variables. Its unusual colours appear to be due to its early spectral type, variability, and high degree of extinction at short wavelengths.

In Fig. 4 is presented the colour-colour plot of [*H* – *K*] versus [*K* – *L'*] for the programme sources. The value of the colour excess ratio *E*(*H* – *K*)/*E*(*K* – *L*) is again highly uncertain and covers a wide range of values from 0·9 ± 0· 4 to 2·08 ± 0·13, as summarised by Tapia (1981).

Lee (1970) gives [*H* – *K*] and [*K* – *L*] values for an M6 III star as 0·33 and 0·30 mag respectively. From a linear extrapolation of his data for M0 III – M6 III stars one finds for an M7 III star [*H* – *K*] 0·36 and [*K* – L] = 0·35 and for an M8 III star [*H* – *K*] = 0·39 and [*K* – *L*] = 0·40. Jones and Hyland (1980) obtained a value for the colour excess ratio *E*(*H* – *K*)/*E*(*K* – *L*) = 1·47 ± 0·10 for a few selected objects in close agreement with the value 1·5 from Becklin *et al.* (1978). The interstellar reddening trajectory corresponding to the slope *E*(*H* – *K*)/*E(K* – *L'*) = 1·47 ± 0·10 passing through the data points for M and K type giants is the hatched region shown as (a) in Fig. 4. Line (b) corresponds to *E*(*H* – *K*)/*E(K* – *L'*) = 1·3 from curve No. 15 of Van de Hulst (as quoted by Tapia 1981). This reddening trajectory seems to account fairly well for the observed colours of the programme

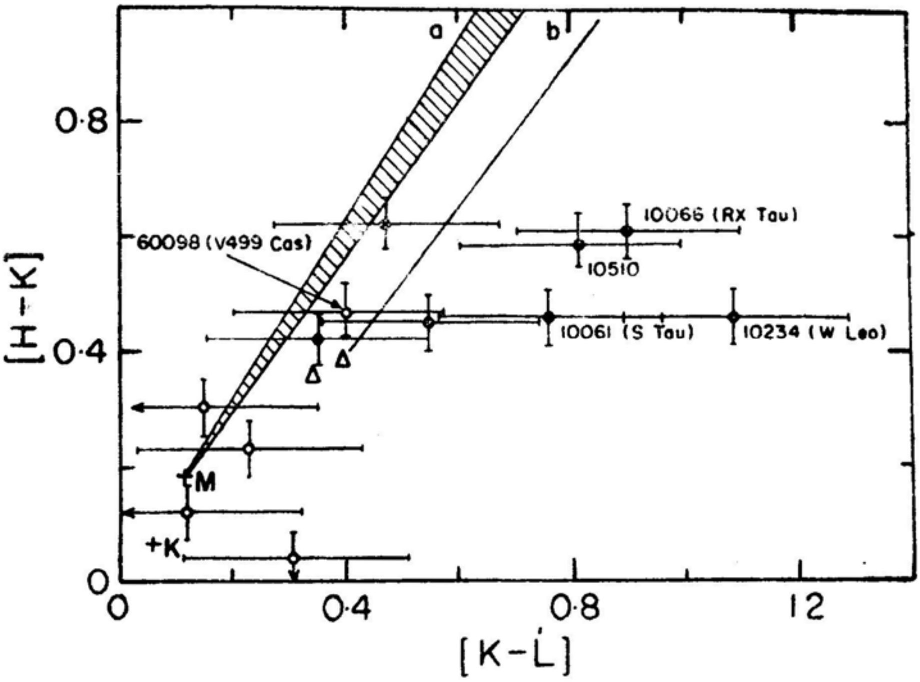

Figure 4. [*H* – *K*] versus [*K* – *L*] colourcolour diagram. The symbols referring to the data points are the same as in Fig. 3. The hatched zone 'a' and the line 'b' are the interstellar reddening trajectories with slope $E(H-K)/E(K-L') = 1{\cdot}47 \pm 0{\cdot}10$, (Jones and Hyland 1980) and $E(H-K)/E(K-L') = 1{\cdot}3$ from Van de Hulst (Tapia 1981). The points corresponding to K and M giants (from Fig. 2 of Jones and Hyland 1980) are indicated by the symbol + and the points corresponding to M7 and M8 giants (obtained from Lee (1970), as explained in the text) are indicated by the symbol Δ.

sources, save those of S Tau, RX Tau, W Leo and SVS 102147. The phase and spectral type at the time of our observation of S Tau, RX Tau, and W Leo, deduced from the time of zero phase and mean period as tabulated by Lockwood (1972) are 0·11 and M5·0,0·72 and M8·5 and 0·63 and M9·0, respectively. Similar data is not available for SVS 102147.

The late spectral types of RX Tau and W Leo at the time of our observation and possible emission from circumstellar material around them are likely to be responsible for their anomalous colours.

5. Discussion

The sources 10061 and 10234 are Mira variables of type M, and are identified as S Tau and W Leo, respectively. They were seen to be brighter in the *K* band during our observation by about 0·4 and 0·3 mag respectively, than during the observation of Neugebauer and Leighton (1969). Source 10061 was noted to be variable by Neugebauer and Leighton (1969). The observed magnitude differences are likely to be due to the differences in the phase at the times of observation.

Source 10066 is a Mira variable of type M and is identified as RX Tau. Its magnitude in the *K* band during our observation agrees well with that obtained by Neugebauer and Leighton (1969). The latter authors did not find any variability in the *I* and/or *K* bands during their survey.

Source 10510 was seen to be highly variable in the *K* band by Neugebauer and Leighton (1969), with its magnitude varying over the range 1·5 to 2·1 during an observing period covering 836 days. It was found to be brighter by 0·8 mag during our observation compared to its mean brightness during the observation of Neugebauer and Leighton (1969). It is identified as SVS 102147 and appears to indicate variability even at 4·2 and 11·0 μm (Price and Walker 1976). It would be of interest to obtain the amplitude of its variation in different wavelength bands and the period of its variability in order to classify it.

Engels (1979), lists the distance to source 10234 (W Leo) as 1224 pc. The value of 200 pc derived for its distance by blackbody fit to our photometric data differs significantly from that of Engels (1979). The discrepancy seems to be due to the insensitivity of our fits to distance. However, the distance to the source can be estimated by using the period-luminosity relation for Mira variables. Wood (1981), gives $M_{\rm bol} = -5{\cdot}82$ for Mira variables of average period 375 days. The apparent bolometric magnitude $m_{\rm bol} \sim 5{\cdot}5$ estimated from our photometric data then yields a distance of ~ 1·7 kpc in fair agreement with that of Engels (1979).

Source 20052 is well outside the galactic plane with $b^{\rm II} = -31°{\cdot}8$. Photometric data on this source are available from Dyck, Lockwood and Capps (1974) and from Strecker and Ney (1974). No significant difference is seen between the *K* band magnitude from this work and that from either Dyck, Lockwood and Capps or from Strecker and Ney. Dyck, Lockwood and Capps derived a colour temperature of 2290 *K* for this source from the flux ratio $F_{1{\cdot}04\mu m}/F_{3{\cdot}4\mu m}$. The fit of the blackbody distribution to the *JHKL'M* magnitudes from this work yields a temperature of 2450 *K* for this source, which does not differ significantly from its colour temperature.

All the sources discussed above have $[I_{\rm CIT} - K] > 5$. Among them, sources 10066, 10510 and 10234 show excess emission at 11·0 μm and source 20052 shows excess emission at 19·8 μm.

Among the sources with $[I_{\rm CIT} - K] < 5$, source 30180 was seen to be fainter in the *K* band by about 0·5 mag during our observation than during the time of survey by Neugebauer and Leighton (1969). It is also seen to be fainter in the *M* band than at 4·2 μm during the AFGL Sky Survey (Price and Walker 1976). It is likely that it is a variable star. Extended observations would help to verify this.

It should be remarked that the temperature derived from blackbody fit to our photometric data turns out to be too high for 60133 and too low for 70073 for their spectral type M2 and K0, respectively. Our *M* band magnitudes of sources 60098, 60133 and 70073 are fainter than the 4·2 jam magnitudes from the AFGL Sky Survey (Price and Walker 1976), by amounts in excess of the estimated errors on these magnitudes. The reasons for these discrepancies are, however, not obvious. Source 60098 (V499 Cas) is an irregular variable; its spectral type and period of variability are not known.

None of the sources with $[I_{\rm CIT} — K] < 5$, show any excess emission up to 4·7 μm.

Acknowledgements

We thank Professor L. Rosino for his kind hospitality at the Asiago Observatory, Italy and Professor J. Trümper, Dr G. Haerendel and Dr S. Drapatz, Max-Planck-Institut für Extraterrestrische Physik, Garching bei München, for their hospitality when one of us (KVKI) was a guest scientist there. We thank Drs T. N. Rengarajan and R. P. Verma of the Infrared Astronomy Group, Tata Institute of Fundamental Research, Bombay, for useful discussions and helpful comments.

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