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THE *JHKL* COLOURS OF GALAXIES

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SUMMARY

JHKL photometry has been attempted for 27 Southern galaxies, mostly barred spirals. In contradistinction to the work of Johnson and others, the values of *K–L* for ostensibly normal galaxies were often found to be much greater than those for normal stars. The general colours of galaxies in this spectral region are discussed, and their fluxes are compared with those obtained at other wavelengths. Two Seyfert galaxies were measured in the infra-red for the first time and shown to possess unexceptional colours. A detailed description of the photometer is included.

INTRODUCTION

Intermediate band infra-red colours of galaxies were first obtained by Johnson (1966) from *JKL* (1·2, 2·2 and 3·5 μ) photometry using an aperture with a diameter of 35″. Ten objects were measured. From this work mean colours for spiral and elliptical galaxies were obtained. Little more has been done on normal galaxies except by Penston (1973, in preparation) who has examined five of them at *H* (1·6 μ) and *K* at various apertures, and one at *L*. *H*, *K* and *L* measurements of M31 were given by Sandage, Becklin & Neugebauer (1969). Other work at these wavelengths has, in general, been confined to Seyfert galaxies (e.g. Pacholczyk & Weymann 1968; Rieke & Low 1971). Some detailed studies of individual objects have also appeared, *viz.* NGC 4151 (Penston *et al.* 1971), NGC 5128 (Becklin *et al.* 1971), NGC 1068 (Neugebauer *et al.* 1971), Zw 0039·5+4003 (Zwicky *et al.* 1970) and IZw 1727+50 (Oke *et al.* 1957).

This study is an attempt to expand our general knowledge of the intermediate band infra-red colours of galaxies. It is believed that this region of the spectrum contains the point at which ordinary radiation from stars starts to be overcome by the processes responsible for the infra-red excesses at long wavelengths and may therefore be of great interest for classification purposes. In addition, *JHKL* photometry is usually more accurate and more sensitive than its counterpart at longer wavelengths.

A total of 27 bright Southern galaxies were chosen from the *Cape Photographic Atlas* (Evans 1957), from Sersic (1968) and de Vaucouleurs (1956), and a few were included at the suggestion of other investigators. Many objects were chosen on the grounds that they possessed bright nuclei or emission lines. Two Southern Seyferts have been measured for the first time as well as many of the brightest barred spirals.

THE PHOTOMETER

The photometer, which may be used at *J*, *H*, *K*, *L*, *M*, *N* and *Q* (1·2, 1·6, 2·2, 3·5, 5, 10 and 20 μ), was constructed during 1971 at the Royal Greenwich Observatory. It has since been used in several programmes on the 18-in. reflector in Cape Town and the 74-in. in Pretoria (e.g. Glass 1972a; Glass & Feast 1973; Feast & Glass 1973).

It consists of two parts: (a) the main frame which contains a star-sky chopper, offset-guider and acquisition eyepiece, and (b) the cryostat which contains the detector.

(a) *The main frame*

Two interchangeable star-sky choppers are the main features of this unit (Fig. 1).

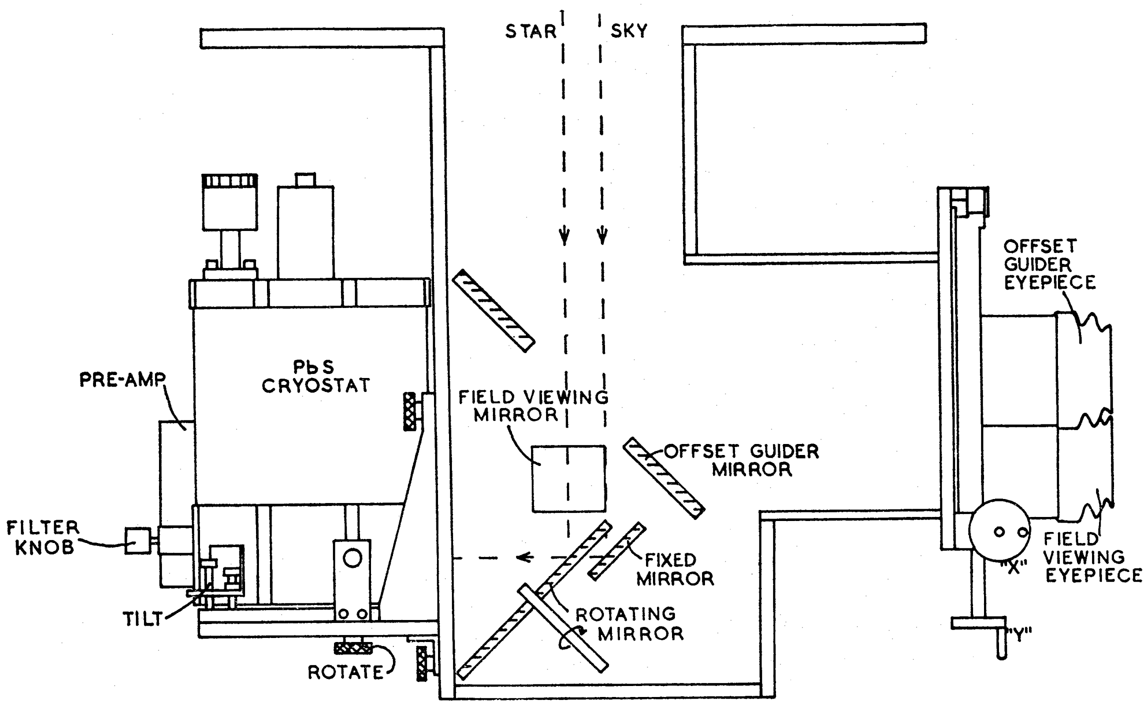

FIG. 1. *General outline of photometer with main body shown in section. The rotary chopper is in place. The stepwise oscillating one may be substituted for it.*

The first one consists of a rotating three-bladed mirror behind which sits an adjustable stationary one. The detector sees the images of star and the sky reflected off the moving and fixed mirrors alternately. The frequency of operation is 12·5 Hz. The stationary mirror is set at the start of a night to nul the thermal radiation from the telescope as far as possible. Its separation from the rotating mirror can be varied from 1·2 cm to 5 cm to permit the measurement of extended sources. This chopper is normally used for J, H, K and L photometry. However, at longer wavelengths (M, N and Q) radiation from the walls of the photometer becomes severe, and spurious signals become sufficiently large to saturate the system. These arise from imperfect nulling and from reflection or diffraction of radiation into the beam of the detector when the edges of the chopper blades pass through it. The alternative chopper was constructed to avoid this problem.

The second chopper consists of a stepwise oscillating flat mirror which deflects the image onto and off the detector at a frequency which can be varied. It is normally operated at 12·5 Hz with a throw of 2 mm. The image must be centred carefully when using this chopper because the finite time necessary for stepping can introduce a significant variation in the response across the aperture. This effect can be reduced at the expense of sensitivity by altering the relative phase of the signal and reference inputs to the phase-sensitive detector. The electrical and mechanical details of the device have been given already (Glass 1972b). A subsidiary black-bladed rotary chopper is provided for optical alignment purposes when this system is being used.

The other parts of the main body of the photometer are the centring eyepiece and the offset guider. The former views the centre part of the telescope beam when a flat mirror is slid into place above the chopper. Its optical train contains a graticule which can be adjusted so that its centre corresponds with the position of the aperture. The offset guider receives the outer parts of the beam from the telescope by reflection from a pierced 45° mirror.

(b) *The cryostats*

There are two interchangeable cryostats, one of which contains a bolometer (M, N and Q bands) and the other a photoconductor (J, H, K and L bands). Each cryostat is attached to a special mount which enables it to be tilted and rotated about the focal point in order to direct the 'antenna pattern' of the detector, defined by its size and the focal length of its Fabry lens, at the secondary mirror of the telescope. The whole assembly can be removed and replaced without disturbing the setting of the cryostats.

The gallium-doped germanium bolometer is a commercial unit (Infrared Laboratories Inc) mounted in an all metal cryostat. It is normally operated at about 2 K by pumping on liquid helium. The Fabry lens of KBr and a fixed focal-plane aperture are cooled to the same temperature as the detector. A slide containing the M, N and Q filters is attached to the radiation shield of the cryostat which is supposed to be at a temperature in the vicinity of 100 K. Radiation enters the vacuum vessel through a KBr window covered with a thin layer of polyethylene to protect it from moisture.

The photo-conductive detector is a chemically-deposited PbS cell donated by Santa Barbara Research Corp. It is mounted behind a CaF_2 Fabry lens, an aperture wheel and a filter wheel in an enclosure which is cooled to 77 K by liquid nitrogen. The cryostat (Fig. 2) was designed and manufactured with assistance from the University College, London, infra-red group. Its vacuum is maintained for long periods by a zeolite sorption pump, and radiation losses are reduced by wrapping many layers of aluminized 'Melinex' foil around the cold parts. The filter and aperture wheels are operated through rotary seals attached to P.T.F.E. rods. The window is of sapphire or CaF_2. The characteristics of the filters are shown in Fig. 3.

OBSERVATIONS

The photometer was attached to the 74-in. Radcliffe reflector in Pretoria or the 40-in. reflector of the South African Astronomical Observatory at Sutherland for the galaxy observations. These telescopes have Cassegrain scales of 6″/mm and 12·6″/mm respectively. The 'sky' diaphragm of the photometer was generally 84″ to the south of the 'star' diaphragm on the 74-in. and about 176″ to the east on the 40-in. The observational procedure is similar to that described by Johnson (1966). The flux in the 'sky' beam due to extended objects is likely to have been

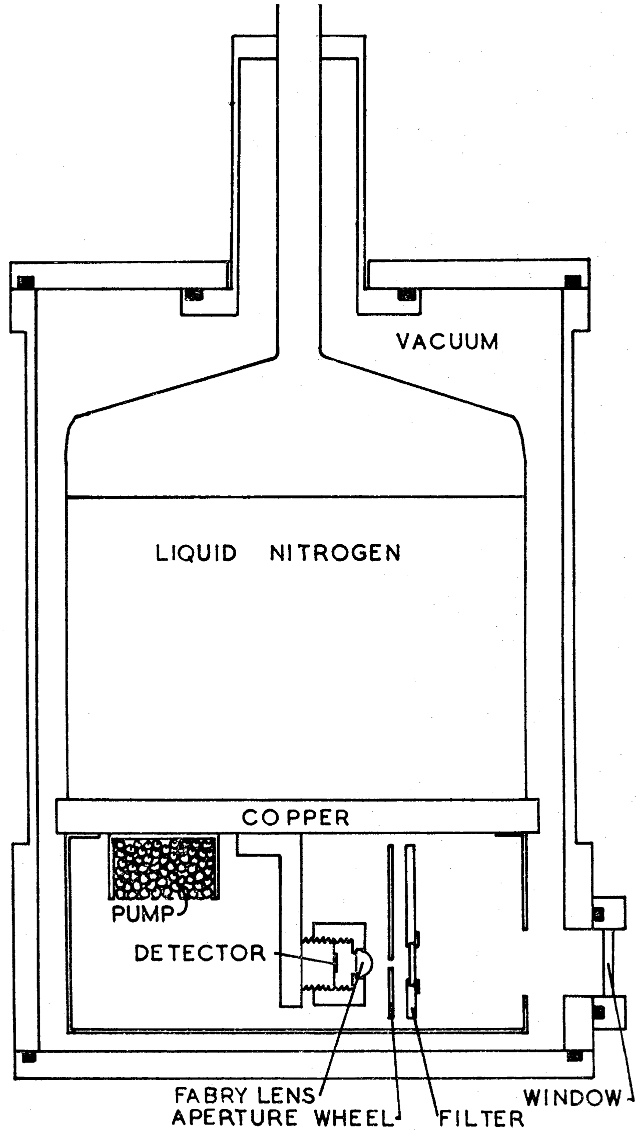

FIG. 2. *Cross-sectional view of the cryostat used to contain the PbS (JHKL) detector. The detector, Fabry lens, apertures and filters are cooled to 77 K. Liquid nitrogen is consumed at the rate of 1 litre/day. The 'hold time' is about 40 hr.*

small and is not allowed for in the data reduction since it is not possible to do this on a satisfactory basis.

A standard aperture diameter of 2 mm was generally adopted but on some occasions other diameters were used to obtain information concerning the dimensions of the sources. Many galaxies were measured more than once to increase the confidence which could be placed on the results.

Infra-red magnitudes were obtained by comparison with stars measured by Johnson *et al.* (1966) with the addition of interpolated *H* magnitudes. The journal of observations is given in Table I. The individual readings were combined where appropriate to obtain the colours which are shown in Table II. The quoted standard deviations arise from statistical fluctuations. Systematic errors are expected to be comparatively small. No corrections for reddening have been applied as these are generally also very small. Notes concerning interesting features of individual galaxies are appended to Table I.

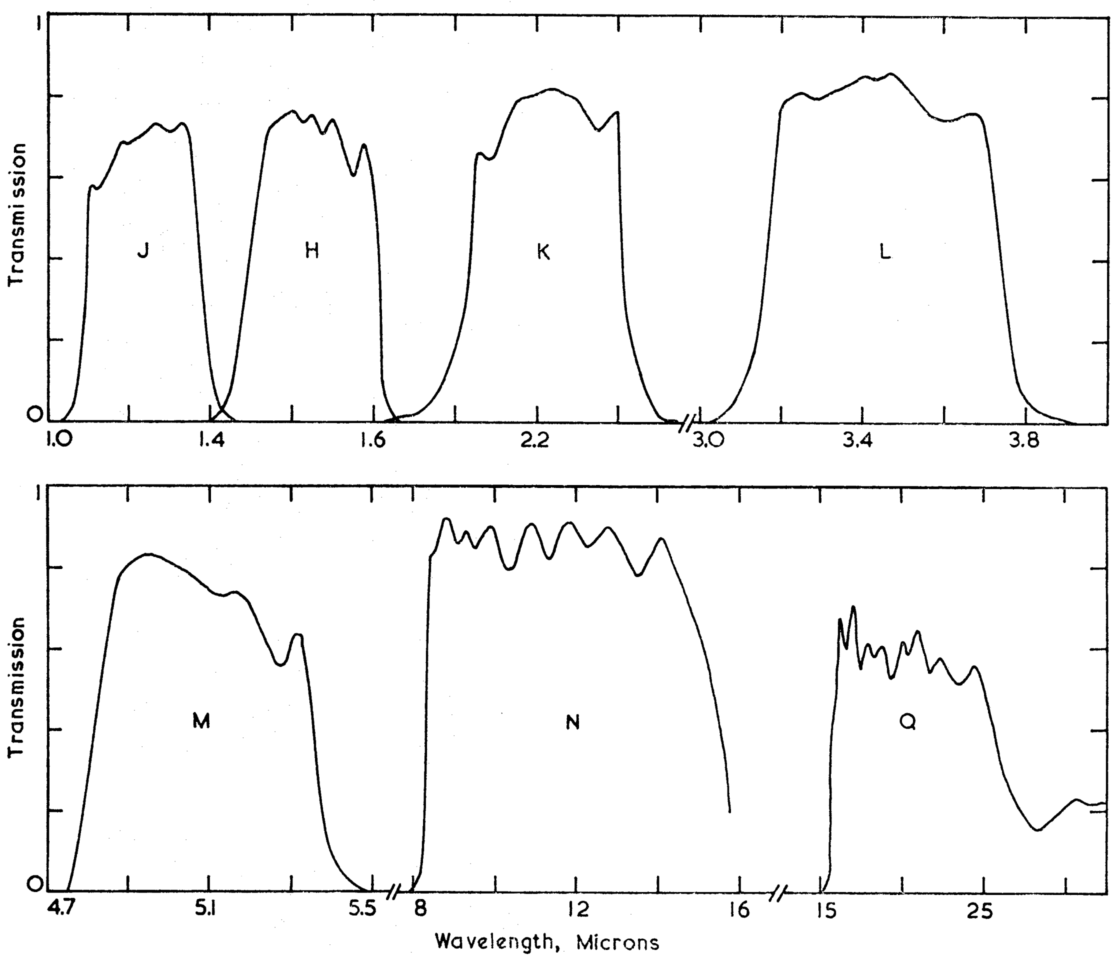

FIG. 3. *Characterists of the filters. The J, H, K and L filters were measured at the operating temperature. The L, M and Q filters were at room temperature. These data were supplied by the manufacturer (OCLI) except in the case of the N and Q filters which were obtained from Infrared Laboratories Inc.* (1·6 *on the upper abscissa should read* 1·8).

DISCUSSION

(a) *The* K–L *index*

The most striking result from Table II is the high incidence of large *K–L* colours. This may be compared with Johnson's (1966) finding, *viz*. that the mean *K–L* for ellipticals is $0^m{\cdot}44$ and for spirals $0^m{\cdot}19$. The value of *K–L* for M31 is $0^m{\cdot}34$ (Sandage *et al.* 1969). Rieke & Low (1972) and Pacholczyk & Weymann (1968) also found large values of this index, but these were for Seyfert galaxies only. The difference between the present results and those of Johnson could arise from either (1) the choice of observed type or (2) the use of smaller apertures which place more emphasis on the nuclear radiation.

The galaxies with the largest *K–L* indices appear in the list of those with peculiar nuclei prepared by Sersic & Pastoriza (1965). NGC 613, NGC 1672, NGC 5253 and NGC 7552 are classified as amorphous type and NGC 1365 and NGC 1808 as ' hot spot ' type. Descriptions of the nuclei of these objects usually contain references to ' dust lanes ' so that it is possible that the infra-red excesses have their origin in thermal radiation from low temperature dust. However, additional photometry is needed to confirm this hypothesis. It should also be noted that

Table I

Journal of observations

NGC No.	Type	Aperture	Telescope	Date	*J*	*H*	*K*	*L*
150	SB(rs)b	3	40	72 Nov. 23	10·70 ± 0·19	9·95 ± 0·49	9·45 ± 0·29	> 5·58
253	SAB(s)c	2	40	72 Dec. 13	8·60 ± 0·09	7·59 ± 0·08	6·90 ± 0·07	6·07 ± 0·13
520	P	2	74	72 Sep. 8			> 11·0	
613	SB(rs)bc	2	40	72 Dec. 13	9·91 ± 0·25	8·99 ± 0·14	8·77 ± 0·21	7·21 ± 0·38
986	SB(rs)ab	2	40	72 Dec. 13	10·04 ± 0·10	9·58 ± 0·31	9·25 ± 0·20	
1097	SB(s)b	2	40	72 Nov. 16		8·27 ± 0·12	7·90 ± 0·11	
		2	40	72 Nov. 26	8·96 ± 0·08	8·14 ± 0·11	7·90 ± 0·09	7·42 ± 0·33
		2	40	72 Dec. 13			7·87 ± 0·09	6·98 ± 0·40
		3	40	72 Dec. 13			7·57 ± 0·09	
1291	(R)SB(s)O/a	2	74	72 Sep. 8	9·18 ± 0·08	8·49 ± 0·07	8·30 ± 0·06	7·65 ± 0·14
		2	40	72 Nov. 17	8·45 ± 0·08	7·67 ± 0·09	7·46 ± 0·10	7·10 ± 0·20
		2	40	72 Jan. 24	8·50 ± 0·08	7·68 ± 0·07	7·47 ± 0·06	6·89 ± 0·29
1313	SB(s)d	2	40	72 Dec. 13			⩾ 9·54	
1316	SAB(s)O°P	2	40	72 Nov. 17	8·54 ± 0·07	7·68 ± 0·04	7·50 ± 0·10	6·79 ± 0·22
		3	40	72 Nov. 26	8·08 ± 0·08	7·32 ± 0·07	6·98 ± 0·07	6·94 ± 0·61
		2	40	73 Jan. 23	8·27 ± 0·08	7·51 ± 0·07	7·34 ± 0·05	6·87 ± 0·24
		1	40	73 Jan. 23			8·07 ± 0·11	
		3	40	73 Jan. 23			7·00 ± 0·06	
		4	40	73 Jan. 23			6·81 ± 0·05	
		2	74	73 Feb. 27	9·18 ± 0·10	8·64 ± 0·09	8·29 ± 0·07	8·18 ± 0·39
		3	74	73 Feb. 27			7·77 ± 0·06	
1365	SB(s)b	2	74	72 Sep. 8	10·59 ± 0·10	9·59 ± 0·14	8·88 ± 0·08	7·46 ± 0·18
		3	40	72 Nov. 23	9·22 ± 0·08	8·21 ± 0·08	7·81 ± 0·09	6·75 ± 0·74
		3	40	72 Nov. 26	8·95 ± 0·09	8·22 ± 0·09	7·71 ± 0·09	6·23 ± 0·25
1487	P	2	74	72 Sep. 27			> 11·15	
1566	SAB(s)bc	2	74	72 Sep. 8	10·63 ± 0·14	9·76 ± 0·14	9·45 ± 0·09	8·82 ± 0·54
	(Seyfert)	2	40	72 Nov. 17	9·92 ± 0·27	9·09 ± 0·17	8·69 ± 0·35	8·08 ± 0·60
		3	40	72 Nov. 26	9·35 ± 0·13	8·49 ± 0·10	8·34 ± 0·08	
		2	40	73 Jan. 23	9·70 ± 0·16	8·91 ± 0·09	8·64 ± 0·11	> 7·23
1672	SB(s)b	2	74	72 Sep. 8	10·09 ± 0·09	9·22 ± 0·07	8·86 ± 0·07	7·85 ± 0·41
		2	40	73 Jan. 22			8·83 ± 0·15	> 6·88
1808	(R)SAB(s)O/a	2	40	72 Dec. 13	9·16 ± 0·16	8·45 ± 0·10	7·94 ± 0·09	6·67 ± 0·40
		2	40	73 Jan. 22	9·15 ± 0·12	8·23 ± 0·11	7·93 ± 0·08	6·89 ± 0·29
		2	40	73 Jan. 23	8·95 ± 0·12	8·13 ± 0·08	7·78 ± 0·06	6·60 ± 0·18
2883		4	74	73 Feb. 28		11·76 ± 0·72		
3256	SB(rs)d	2	40	73 Jan. 23	10·26 ± 0·20	9·81 ± 0·19	8·78 ± 0·43	8·24 ± 0·76
3783	SB(r)a	2	74	72 June 6	10·79 ± 0·21	10·32 ± 0·10	9·87 ± 0·17	> 7·91
	(Seyfert)	2	40	72 Dec. 12		9·81 ± 0·23	9·61 ± 0·37	
		2	40	73 Jan. 27		9·90 ± 0·16	9·43 ± 0·21	
		2	74	73 Feb. 26	11·02 ± 0·20	10·43 ± 0·16	9·88 ± 0·14	> 8·78

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TABLE I—*continued*

NGC No.	Type	Aperture	Telescope	Date	*J*	*H*	*K*	*L*
4507	SAB(r)O+	2	74	73 Feb. 27	11·68±0·28	10·64±0·19	10·07±0·12	>8·86
5236	SAB(s)	4	74	72 June 2	8·58±0·07	7·89±0·07	7·53±0·05	
=M83)		2	40	73 Jan. 23	8·41±0·07	7·65±0·07	7·40±0·06	6·62±0·19
		2	74	73 Feb. 28	9·32±0·10	8·49±0·08	8·32±0·10	7·88±0·20
		3	74	73 Feb. 28			7·70±0·05	
		4	74	73 Feb. 28			7·44±0·05	
5253	IBmP	2	74	72 Jun. 27		11·38±0·65	10·55±0·26	>8·78
		2	74	73 Mar. 29		11·44±0·19	10·72±0·22	8·78±0·59
6753	(R)SA(r)b	2	74	72 June 27		9·76±0·15	9·35±0·10	
6769	SAB(r)bP	2	40	72 Nov. 23			>10·4	
7496	SB(s)B	2	74	72 Sep. 8			>11·0	
7552	(R)SB(s)ab	2	74	72 Sep. 8	10·12±0·20	9·30±0·10	8·95±0·07	7·63±0·10
7582	(R)SB(s)ab	2	74	72 Jul. 3		9·55±0·08	8·90±0·08	7·85±0·16
		2	74	72 Sep. 8	10·45±0·11	9·65±0·11	8·92±0·08	8·19±0·32
7590	SA(rs)bc:	2	74	72 Sep. 8	>11·94	>11·29	>11·27	
7793	SA(s)dm	2	74	72 Sep. 8	12·4±0·7	11·7±0·3	10·8±0·4	>8·44

Notes to Table I

253 Weak radio source. Becklin & Neugebauer (1972) see an infra-red source 20″ in diameter similar to that in M82.
613 Burbidge *et al.* (1964) state nucleus is 12″ in diameter. Sersic (1968) says it resembles a small spiral. H II regions and dark filaments exist near nucleus.
986 Bright nucleus surrounded by dark lenses.
1097 ' There is a central very small amorphous nucleus only about 8″ in diameter, surrounded by a segmented annulus consisting of bright areas and probably dust.' (Burbidge & Burbidge 1960). Non-circular motions are apparent in this galaxy and also NGC 1365.
1291 Sersic (1968) says this is the SO of largest apparent dimensions. de Vaucouleurs (1961) saw a ' hot spot '.
1313 Nebulosity visible, no absorbing material (Evans 1957).
1316 Fornax A radio source. The radio flux comes from two large areas extending well beyond the visible boundary of the galaxy.
1365 Nucleus has ' hot spots arranged in spirals and separated by a well marked dark filament ' (Burbidge & Burbidge 1960).
1487 Possesses 3 nuclei; called ' Peculiaridad Extrema ' by Sersic (1968).
1566 Generally considered a Seyfert. Hβ has shown changes (Pastoriza 1971). Member of Dor group.
1672 ' Filaments of dark material emerging from a very bright nucleus of peculiar nature ' (Sersic 1968). Sersic & Pastoriza (1965) classify the nucleus as amorphous.
1808 Many dark lanes (Evans 1957). Hot spots in nucleus according to Sersic & Pastoriza (1965).
2883 ' Peculiaridad Extrema ' (Sersic 1968).
3256 ' Peculiaridad Extrema ' (Sersic 1968). Nuclear region of two bright fragments 22″×6″ and 28″×20″ separated by a 2″ wide dark furrow.
3783 Possesses Seyfert character. Page (1967), Martin (1973, private communication).
4507 Classified as N-type (Martin 1973, private communication).
5236 Peculiar nucleus with large concentrations of not spots (Sersic & Pastoriza 1965). Member of Centaurus group which includes NGC 5128.
6753 Small stellar nucleus (Sersic 1968).
6769 Part of Trio in Pavo. Each component has an exceptionally bright nucleus. Unstable by virial theorem (Sersic 1968).
7496 Emission lines and intense *UV* continuum. Very bright nucleus (Sersic 1968).
7552 Member of quartet in Gruis. Peculiar nucleus of amorphous type (Sersic & Pastoriza 1965).
7582 Member of quartet in Gruis. Nucleus small and bright with numerous condensations of obscuring material in it (Sersic 1968). System dissociating Shobbrook (1966).
7590 Central region very bright (Sersic 1968).
7793 Almost stellar nucleus (Sersic 1968).

TABLE II

The colours

NGC	*J–H*	*H–K*	*K–L*	Aperture (mm)	Telescope (inches)
150	0·75 ± 0·53	0·50 ± 0·57	—	3	40
253	1·01 ± 0·12	0·69 ± 0·11	0·83 ± 0·15	2	40
613	0·92 ± 0·29	0·22 ± 0·25	1·56 ± 0·43	2	40
986	0·46 ± 0·33	0·33 ± 0·37	—	2	40
1097	0·75 ± 0·12	0·32 ± 0·10	0·65 ± 0·25	2	40
1291	0·69 ± 0·11	0·19 ± 0·09	0·65 ± 0·15	2	74
	0·80 ± 0·08	0·21 ± 0·08	0·44 ± 0·11	2	40
1316	0·81 ± 0·10	0·17 ± 0·10	0·59 ± 0·17	2	40
	0·76 ± 0·11	0·34 ± 0·10	0·04 ± 0·61	3	40
	0·55 ± 0·13	0·35 ± 0·11	0·11 ± 0·40	2	74
1365	1·00 ± 0·17	0·71 ± 0·16	1·42 ± 0·20	2	74
	0·88 ± 0·12	0·45 ± 0·05	1·53 ± 0·26	3	40
1566	0·87 ± 0·20	0·31 ± 0·17	0·63 ± 0·55	2	74
	0·81 ± 0·17	0·31 ± 0·12	0·56 ± 0·60	2	40
	0·86 ± 0·15	0·15 ± 0·13	—	3	40
1672	0·87 ± 0·11	0·36 ± 0·10	1·01 ± 0·42	2	74
1808	0·82 ± 0·13	0·39 ± 0·12	1·20 ± 0·22	2	40
3256	0·45 ± 0·28	1·03 ± 0·47	0·54 ± 0·87	2	40
3783	0·53 ± 0·23	0·51 ± 0·14	—	2	74
	—	0·34 ± 0·25	—	2	40
4507	1·04 ± 0·34	0·57 ± 0·22	—	2	74
5236	0·69 ± 0·10	0·36 ± 0·08	—	4	74
(=M83)	0·76 ± 0·10	0·25 ± 0·10	0·78 ± 0·20	2	40
	0·83 ± 0·13	0·17 ± 0·13	0·44 ± 0·22	2	74
5253	—	0·80 ± 0·27	1·86 ± 0·62	2	74
6753	—	0·41 ± 0·18	—	2	74
7552	0·82 ± 0·22	0·35 ± 0·12	1·32 ± 0·12	2	74
7582	0·87 ± 0·13	0·67 ± 0·08	0·99 ± 0·15	2	74
7793	0·7 ± 0·8	0·9 ± 0·5	—	2	74

most of these galaxies have spectra with emission lines, so that free-free radiation may also contribute towards the infra-red radiation. It is clear from these observations that possession of an infra-red excess is not contingent upon Seyfert spectral characteristics.

(b) *General colour characteristics*

Fig. 4(a), (b) and (c) shows histograms of the *J–H*, *H–K* and *K–L* colours. The dispersions show a marked increase with wavelength, presumably due mostly to the increasing contributions from non-stellar radiative processes. Colours with probable errors greater than $0^{m}\cdot5$ have been omitted. Fig. 4(d), (e) and (f) shows the *J–K* colours found by Johnson, those found during this work and both together. The most frequent value of *J–K* from the histogram is 1·15, of *J–H*, 0·85 and of *H–K*, 0·35.

Fig. 5(a) and (b) show two of the colour–colour diagrams which may be constructed. The *J–H*, *H–K* diagram shows a pronounced clumping slightly to the left of the blackbody line at about the position of M-type stars. The deviation from blackbody colours is explicable by the H-band opacity minimum in the atmospheres of late-type stars. Care must be taken in interpreting the positions of individual points in this and in the other diagrams as they are often derived from measurements with high statistical errors.

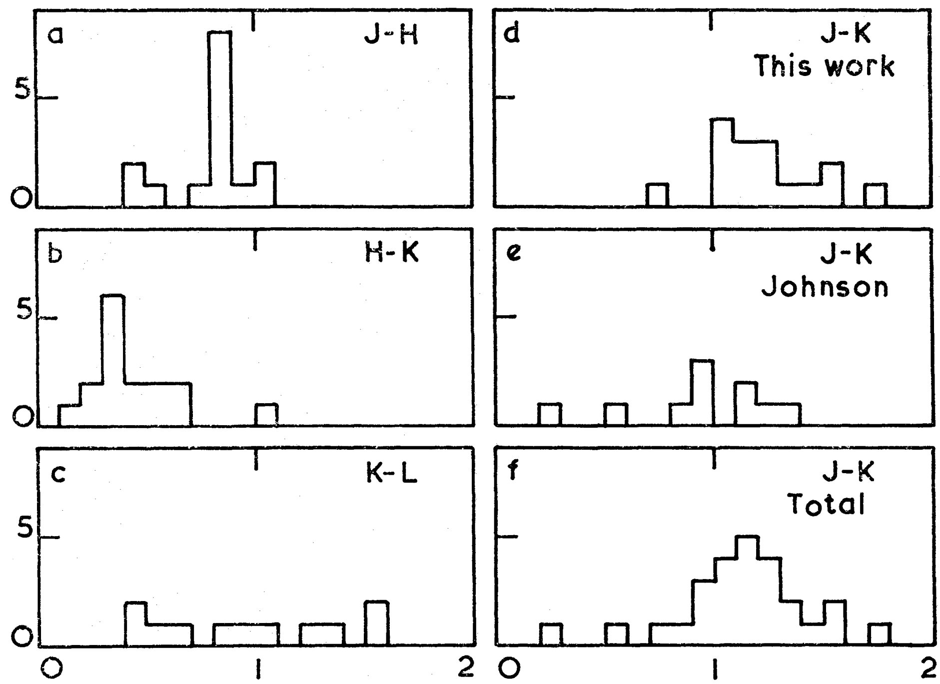

FIG. 4. *Histograms of observed colour indices for galaxies. The J–H and H–K diagrams show peaks at the positions characteristic of M-type stars. The K–L index shows considerable scatter indicating that the fluxes from most of the galaxies in the sample have some non-stellar component at long wavelengths.*

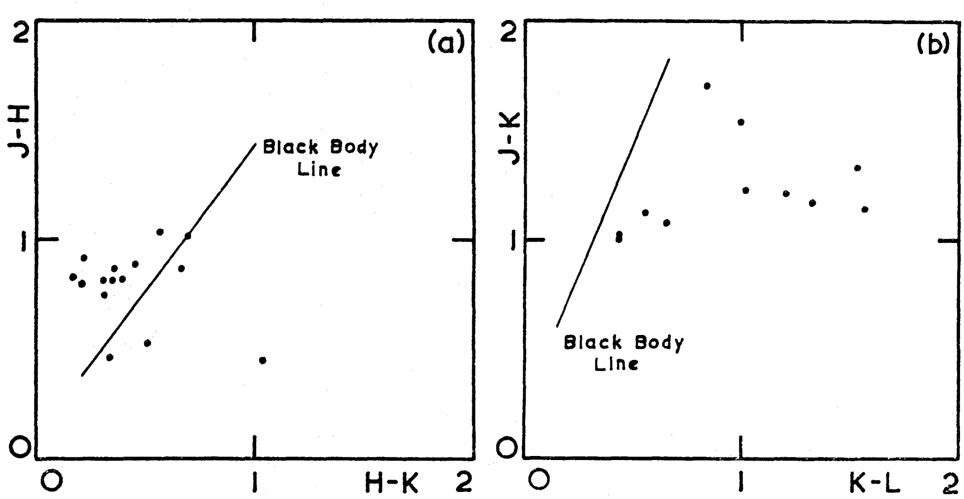

FIG. 5. *Colour–colour diagrams of galaxies. (a) shows a clumping around J–H = 0·8, H–K = 0·2 characteristic of late-type giants. The diagram (b) shows the L-excesses which move the colours away from the blackbody line.*

The *J–K*, *K–L* diagram shows all points lying to the right of the blackbody line due to *L* excesses. Their position can be readily explained by combinations of normal stellar radiations and dust at a temperature of a few hundred degrees. The *K–L* colours are therefore of little use in studying the stellar populations of galaxies.

(c) *Variation of flux with aperture size*

For three glaxies, NGC 1316, NGC 1566 and NGC 5236 (M83), measurements were made with several aperture sizes, permitting the determination of the degree to which the radiation was concentrated about the nuclei.

Fig. 6 shows the logarithmic plots of flux *vs.* aperture diameter for all cases where readings were taken with more than one aperture.

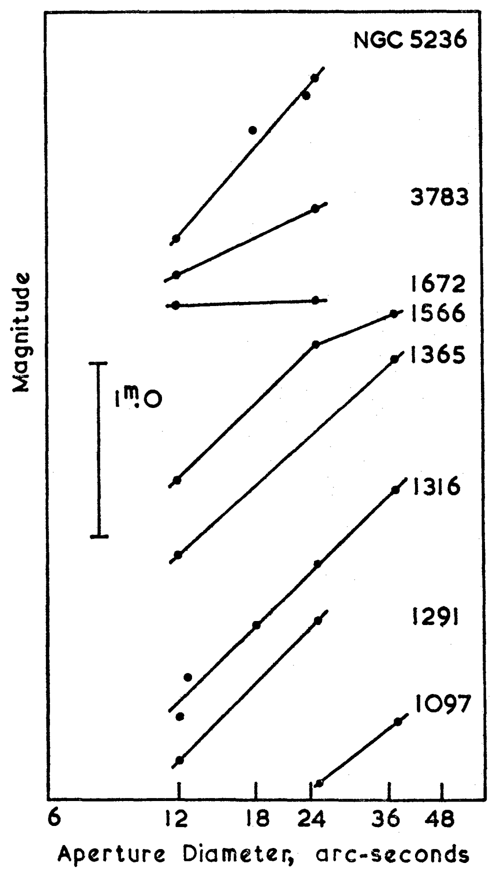

FIG. 6. *Variation of flux with aperture size.*

A straight horizontal line represents a point source, and one with a slope of 2 a uniformly bright one. The bright galaxy M83 is the least concentrated, but it must be remembered that it appears very large in comparison with the other two well-determined cases. NGC 1316 appears to be quite concentrated. This result was confirmed by a slow scan. Photographs of it show an irregular dust feature near its centre (Burbidge 1964). NGC 1566 shows a similar moderate degree of concentration.

(d) *The quartet in Gruis*

Two of the galaxies with strong *K–L* excesses, NGC 7552 and NGC 7582 are considered to form part of a quartet (Sersic 1968). They are also radio sources. They have already been dealt with in more detail (Glass 1973). No evidence for interaction between the members is visible on the Palomar Sky Atlas prints.

(e) *The Seyfert galaxies NGC* 1566 *and NGC* 3783

Two Seyfert galaxies, the relatively well known NGC 1566 and also NGC 3783 (Page 1967) were included in the programme. The Seyfert character of NGC 3783 has been confirmed and its spectrum analysed in detail by Martin (1973, private communication). Neither galaxy shows marked peculiarity in its J–H or H–K indices. The K–L colour of NGC 1566 of about $0^{m}\cdot6$ is comparable with Rieke & Low's (1972) value for NGC 7469, and considerably less than their average for five Seyfert galaxies of 1·5. However, NGC 1566 is sometimes described as being a weak exhibitor of Seyfert character. Unfortunately, NGC 3783 was too faint to detect at 3·5 μ, but it can be stated that K–$L < 1\cdot0$ at 3σ confidence level.

A measurement at N (10 μ) with an aperture of diameter 10″ and a beam separation of 12″ on 1972 June 28 set a lower limit to the magnitude of NGC 1566 of $3^{m}\cdot6$. From these observations it appears that Seyfert spectral characteristics do not always imply the possession of a strong infra-red excess.

(f) *Comparison with data from other spectral regions*

Many of the galaxies in this survey have also been measured in the radio spectral region (Slee 1972a, b; Cameron 1971; Whiteoak 1970; Shimmins 1971). NGC 1316 is the well-known bright double source Fornax A. Most of the others are unresolved, but NGC 253 and NGC 5236 show evidence of a disc component. Slee (1972b) points out that many galaxies show anomalies at the low frequency end of their spectra. Of the five galaxies common to his list of such cases and this study, three (NGC 253, NGC 1808 and NGC 7582) have large K–L indices while the other two (NGC 1097 and NGC 5236) have some excess in K–L.

Precise comparisons of radio and infra-red fluxes are difficult to make because of the different and sometimes unknown angular sizes of the sources involved. However, in many cases they are sufficiently small that most of their radiation falls within the circumference of the aperture employed. Fig. 7 shows a rough plot of flux versus frequency for those galaxies with measurements in both parts of the spectrum. Optical points have been included for NGC 7552 and NGC 7582, taken by Andrews (1973, private communication) with the same size of aperture as was used in the infra-red.

In addition, three galaxies from Rieke & Low's (1972) list of objects measured at 10 and 20 μ (N and Q) have been included, although the aperture used by them is only 6″ diameter. The N and Q fluxes from M83 (NGC 5236) have been arbitrarily increased by a factor of 16 to compensate for the difference in aperture sizes since the nucleus of this relatively nearby galaxy appears quite large as already mentioned.

An examination of Fig. 6 reveals two systematic trends; that (1) the radio spectrum usually is of the form $f \propto \nu^{-\alpha}$ where $\alpha \sim 0\cdot75$ and (2) the flux in the intermediate infra-red region is linearly related to its high-frequency radio counterpart with one or two exceptions.

The spectrum of NGC 5253 has a large hump at 20 μ. This object is classed as a peculiar irregular barred galaxy of Magellanic type by the de Vaucouleurs (1964). Burbidge & Burbidge (1962) describe the nucleus as consisting of condensations which emit strongly in high-excitation emission lines e.g. [O III], [Ne III] etc. The other two galaxies measured in the far infra-red, NGC 253 and M83 also show long-wavelength excesses, as might have been predicted from their K–L colours.

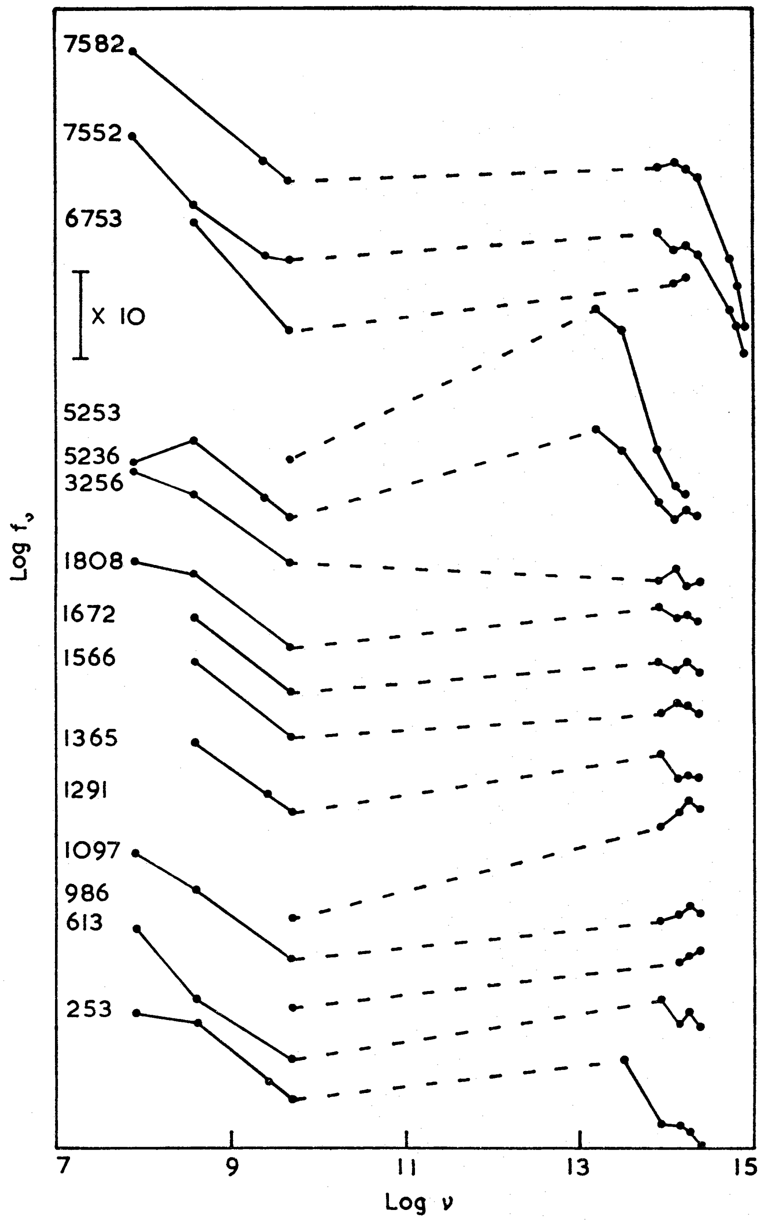

FIG. 7. *The spectra of* 15 *galaxies for which both radio and infra-red measures exist. The magnitudes were converted to fluxes according to the calibration of Becklin, quoted by Glass & Feast* (1973*b*, *in preparation*). *The sources of the data outside the JHKL region are given in the text.*

CONCLUSIONS

It has been shown that the *J–H* and *H–K* colours of the bright Southern barred spiral galaxies are, in general, similar to those of late type stars, but that the *K–L* colours are not. The excesses which are observed at *L* may arise from thermal radiation from dust or from free-free processes. Some of the galaxies with the highest values of *K–L* have been described as possessing 'hot spots'. Seyfert spectroscopic features do not always imply marked infra-red excesses and vice versa. The intermediate-band infra-red spectral intensity is found to be closely correlated with its radio-frequency counterpart.

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