AFCRL-72-0016

GROUNDBASED INFRARED OBSERVATIONS OF CELESTIAL SOURCES

by

Frank J. Low

University of Arizona
Tucson, Arizona 85721

Contract No. F19628-70-C-0046
Project No. 8692

SEMI-ANNUAL TECHNICAL REPORT NO. 3

31 August 1971

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13. ABSTRACT

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I. SKY SURVEY DATA REDUCTION

In Semi-Annual Technical Report No. 2, dated 28 February 1971, the observational results of our 10 micron groundbased sky survey were summarized.[1] This summary was based on preliminary reductions of about half of the total observations. Reduction of these data has been continued, but results given in the previous report have not been significantly altered.

II. MODIFICATIONS TO THE 28" TELESCOPE

The ultimate sensitivity of the groundbased infrared telescope is determined by the total background power falling on the detector. It has been shown that for all telescopes used for 5, 10 and 20 micron photometry, the radiation emitted by the telescope itself is far greater than the radiation emitted by the sky. Since it is possible, in principle, to reduce the telescope emission to a level below the emission of the sky, significant improvement in sensitivity should be achievable. Since the 28" telescope is used principally for infrared observations, we have undertaken a program to enhance the infrared performance by minimizing the emission of the telescope.

Optical telescopes are generally constructed with large central obscuration by the secondary optics. In Cassegrain telescopes, there is usually a large hole in the center of the primary mirror which permits access to the Cassegrain focus behind the primary. In order to reduce the emission from this source, we changed from a large over-sized F16 secondary to a slightly under-sized F45 secondary. The diameter of the new secondary is 2.40", which obscures less than 1% of the primary. The central hole in the primary has been reduced to 2.0". The three spiders supporting the secondary add about 20% to the obscuration. The focusing mechanism and the mechanism which actuates the secondary for modulation purposes have been designed so that they cannot be seen by the detector array at the Cassegrain focus. Since the secondary mirror is slightly undersized, it serves as a "cold stop". In the usual telescope design, the secondary is somewhat over-sized, which permits the infrared detector to see beyond the edge of the primary, which is generally a highly emissive part of the telescope. Now these edge rays look directly at the sky, which has a surface brightness less than that of the least emissive parts of the telescope.

Once the above changes were made, it became apparent that the residual emission from the telescope would be determined by the emissivity of the mirror coatings. Formerly, these coatings were standard optical coatings of thin aluminum. Aluminum coatings were replaced with vacuum deposited silver. We are now in the process of evaluating the lifetime and emissivity of these silver coatings under actual telescope conditions. Laboratory measurements indicate sizeable reduction of emissivity.

During the same period that the optical changes were being made, a number of changes in the mounting were carried out. Both the declination and right ascension drives now utilize high speed, high resolution digital motors which are capable of producing all tracking and slewing operations. It is now possible to position the telescope to an accuracy of better than ±1 arcminute by simple digital means. These changes also facilitate operating the telescope in the scanning mode.

In the Semi-Annual Technical Report #2, performance of the four detector systems which have been developed under this program were summarized and compared. The most sensitive system was the four-detector array operated on the 61" telescope at F45. This system can now be used directly on the 28" telescope and should have comparable sensitivity because of the lower background. A larger field of view is realized because of the smaller scale of the 28" relative to the 61" (6 arcseconds/mm vs. 3 arcseconds/mm).

III. ABSOLUTE CALIBRATION

Johnson's (1965) calibration of the KLMN infrared photometric system[2] was based on observations of stars similar to the sun. At the time of his work, sufficiently sensitive apparatus was not available to measure these stars at M(5μ) or N(10μ); the M and N magnitudes had to be extrapolated from measurements at shorter wavelengths and from observations of brighter stars at M and N. Direct observations of stars similar to the sun have now been obtained; the results are summarized in Table 1. The measurements differ by about 24% from the values adopted by Johnson at N.

The method used by Johnson is based on an analogy between the sun and other stars of similar spectral type utilizing the known absolute flux of the sun; a measurement which refers directly to a black body source will be carried out soon. The data presented in Table 1 indicate that a fairly substantial revision of Johnson's calibration will result from this experiment.

TABLE 1

Color

	V-K	V-M	V-N
Johnson	1.41	1.40	1.46
New Observations	1.42 ± .02	1.54 ± .05	1.69 ± .03
Difference	0.01 ± .02	0.14 ± .05	0.23 ± .03

IV. EXTRAGALACTIC INFRARED SOURCES

The most powerful infrared sources in the universe are found in the nuclei of galaxies and quasars.[3-13] In the previous report,[14] we summarized the status of our observations of galaxies and quasars. The number of objects observed and the quality of the observations have been considerably improved and the following table lists these results. Note that this table gives the name of the galaxy, its morphological type, the 10μ flux density, the error of the measurement stated in flux units and computed as a standard deviation, the best estimate of the distance, and in the last column the luminosity of the galaxy at 10μ referred to the luminosity at 10μ of the nucleus of our own galaxy.

Our ultimate goal is to understand the physical nature of these enormously powerful infrared sources. However, it is also important to know what contribution galaxies make to the overall cosmic background. As can be seen from the present observations, the phenomenon is associated with certain types of galaxies. Once these relationships are known, it should be possible to extrapolate these results to include all the galaxies in the universe.

EXTRAGALACTIC SOURCES AT 10μ

Name	Type	10μ Flux Den. (flux units)*	St. Dev. (flux units)*	Distance (Mpc)	L at 10μ (L of gal. center)
I Zw 1	Seyfert galaxy	.40	.04	240	4.5×10^{5}
NGC 1275	Seyfert galaxy	1.03	.03	70	1.0×10^{5}
Markarian 9	Seyfert galaxy	.21	.05	150	9.3×10^{4}
3C 120	Seyfert galaxy	.28	.05	120	8.0×10^{4}
NGC 1068	Seyfert galaxy	22(v)		13	7.3×10^{4}
NGC 7469	Seyfert galaxy	.78	.05	67	6.9×10^{4}
NGC 5548	Seyfert galaxy	.18	.06	67	1.6×10^{4}
NGC 2782	Seyfert galaxy	.26	.06	34	5.9×10^{3}
NGC 4151	Seyfert galaxy	1.24	.04	13	4.1×10^{3}
NGC 3227	Seyfert galaxy	.34	.06	14.5	1.4×10^{3}
NGC 4051	Seyfert galaxy	.31	.05	9.3	530
Markarian 10	Seyfert galaxy	$\leq .20$		110	$\leq 4.7 \times 10^{4}$
NGC 3516	Seyfert galaxy	$\leq .6$		37	$\leq 2.4 \times 10^{4}$
NGC 6814	Seyfert galaxy	$\leq .15$		25.1	$\leq 1.9 \times 10^{3}$
NGC 3034	I0 P	27	1	4.0	8.5×10^{3}
NGC 7714	Sb P	.25	.04	36.8	6.6×10^{3}
NGC 1052	E4	.19	.03	19	1300
NGC 4303	Sbc	.24	.06	14.5	1000
NGC 253	Sc	6.2	0.5	2.5	760
NGC 3077	I0 p	7.3	1.5	3.3	700
NGC 4569	Sab	.17	.03	14.5	700
NGC 3675	Sb	.28	.10	10	550
NGC 4192	Sab	.10	.03	14.5	410
NGC 2903	Sbc	.33	.05	6.8	300
NGC 5195	I0 P	.29	.06	6.3	220
NGC 6946	Scd	.56	.04	4.2	190
NGC 4736	Sab	.32	.06	5.2	170
NGC 5236	Sc	.55	.09	4.0	170
NGC 4826	Sab	.094	.026	7.2	96
NGC 5457	Scd	.20	.07	4.0	63
Maffei 1		.072	.033	1.0	1.4
Galactic Center		510	40	.010	1.00
NGC 221	dE2	.089	.019	0.7	0.9
NGC 4670	S0/a	≤ 3.5		16	$\leq 1.8 \times 10^{4}$
NGC 5713	Sbc	≤ 1.8		13.2	$\leq 6 \times 10^{3}$
NGC 5253	Im	≤ 3.5		4.0	$\leq 1.1 \times 10^{3}$
NGC 1232	Sc	$\leq .11$		23	$\leq 1.1 \times 10^{3}$
NGC 4654	Scd	$\leq .23$		14.5	≤ 950
NGC [illegible]	E2	$\leq .15$		14.5	≤ 660
NGC 4651	Sc	$\leq .15$		14.5	≤ 620
NGC [illegible]	S0	$\leq .14$		14.5	≤ 550
NGC 1097	Sb	$\leq .09$		17	≤ 510
NGC 4649	E2	$\leq .12$		14.5	≤ 500
NGC 4579	Sb	$\leq .12$		14.5	≤ 500
NGC 4406	E3	$\leq .12$		14.5	≤ 490
NGC 4552	S0	$\leq .11$		14.5	≤ 450

*Flux units = 1×10^{-26} W/m²/Hz = 3.0×10^{-18} W/cm²/μ

EXTRAGALACTIC SOURCES AT 10μ (cont.)

Name	Type	10μ Flux Den. (flux units)*	St. Dev. (flux units)*	Distance (Mpc)	L at 10μ (L of gal. center)
NGC 5055	Sbc	≤ .30		8	≤ 380
NGC 4382	SO	≤ .12		10.5	≤ 260
NGC 4278	E1	≤ .13		8.2	≤ 170
NGC 628	Sc	≤ .08		10	≤ 160
NGC 2683	Sb	≤ .07		10	≤ 140
NGC 5194	Sbc	≤ .17		6.3	≤ 130
NGC 7331	Sbc	≤ .06		10	≤ 120
NGC 4258	Sbc	≤ .21		4.4	≤ 80
NGC 3115	SO	≤ .11		5.6	≤ 68
NGC 247	Sd	≤ .12		2.5	≤ 15
NGC 185	dEO	≤ .13		0.7	≤ 1.3
NGC 205	dE6	≤ .12		0.7	≤ 1.2
NGC 147	dE4	≤ .11		0.7	≤ 1.1
NGC 224	Sb	≤ .072		0.7	≤ 0.7
NGC 598	Sc	≤ .049		0.8	≤ 0.6
Cyg A	radio galaxy	.18	.03	220	1.7×10^{5}
Cen A	radio galaxy	3.3**	0.9	4.0	1000
OJ 287	var. radio object	.68	.04		
BL Lac	var. radio object	.52	.02		
II Zw 40	compact galaxy	.13	.06	7	120
IV Zw 149	compact galaxy	≤ .13		43	$\leq 4.7 \times 10^{3}$
VV 254	interacting galaxy	≤ .11			
3C 232	quasi-stellar object	.16	.04	1600	8×10^{6}
3C 323.1	quasi-stellar object	.10	.03	920	1.7×10^{6}
3C 273	quasi-stellar object	.23	.02	580	1.5×10^{6}
3C 351	quasi-stellar object	≤ .05		1200	$\leq 1.4 \times 10^{6}$
3C 48	quasi-stellar object	≤ .08		1200	$\leq 2.3 \times 10^{6}$

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*Flux units = 1×10^{-26} w/m^2/Hz = 2.5×10^{-18} w/cm^2/μ

**Centaurus A was observed by Becklin, E. E., Frogel, J. A., Kleinmann, D. E., Neugebauer, G., Ney, E. P., and Strecker, D. W., Ap. J. (Letters) 170, L15 (1971).

V. VARIABLE INFRARED STARS

The variable star V1057 Cyg has been observed intensively. Sometime in late 1969, this object changed from a T-Tauri-type star with M_{pg} $\sim 16^m$ to a high luminosity A1-type star, with a blue magnitude $\sim 10\overset{m}{.}7$ (Welin, 1971; Herbig and Harlan, 1971). Observations after this brightening show the object to have a strong infrared excess with a magnitude at N of $\sim 0\overset{m}{.}2$. No infrared data are available for the time before the star brightened; however, the observed infrared flux is considerably stronger than would be expected from an M_{pg} $\sim 16^m$ T-Tauri-type star. Thus, V1057 Cyg may represent a class of objects which can brighten considerably at 10μ.

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