Publications of the Astronomical Society of the Pacific
103: 987–997, September 1991

JHK INFRARED STANDARD STARS AND ABSOLUTE CALIBRATION OF THE SAN PEDRO MARTIR OBSERVATORY (OAN) PHOTOMETRIC SYSTEM[1]

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Received 1991 May 3, revised 1991 May 24

ABSTRACT

A set of reliable standard stars for the *JHK* photometric system of the San Pedro Mártir National Observatory (OAN) is presented. Mean extinction coefficients for the near IR of this site are first reported here; effective wavelengths and flux calibration from observations of Vega are derived for the various bandpasses. Comparison with other widely used photometric systems is presented and, finally, transformation equations to CIT, AAO, ESO, and Johnson's systems are derived.

Key words: near-infrared–photometry–standard stars

1. Introduction

The reliability and usefulness of any photometric system are determined essentially by the stability of the set of standard stars combined with a proper reduction and treatment of the data. Furthermore, one is ultimately more interested in obtaining monochromatic fluxes at the effective wavelengths of a given photometric system than simple magnitudes of astronomical objects. Since 1984 an InSb infrared photometer has been operated at the 2.1-m telescope of the Mexican National Astronomical Observatory (OAN) located at San Pedro Mártir, B.C. (Roth et al. 1984). A first attempt to produce a set of standard stars for this photometric system was published by Tapia, Neri & Roth 1986. The present group of authors has been using this system extensively and since 1985 has noticed that the original set of standard stars presented a combination of erratic behavior as well as systematic trends when confronted with other photometric systems. Some internal inconsistencies in the Tapia et al. 1986 standard set of stars were found as well. A criticism of the previous work is that it lacked adequate atmospheric extinction determinations and, hence, data were reduced by adopting the mean extinction measured at La Silla (ESO) in the Southern Hemisphere, hoping that the conditions of both sites were similar. Our determinations of the atmospheric extinction at San Pedro Mártir proved that the latter is not the case.

Due to the problems outlined above we decided to generate a new list of standard stars that would be nonvariable in principle, based on abundant previous measurements as given in the compilation of Gezari, Schmitz & Mead 1984. We chose stars faint enough so that detector saturation problems would not occur in a 2-m class tele-

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scope. We have used this set of standards systematically during 170 photometric nights distributed in the period 1984–89.

The overlapping of our sample of standard stars with other sets allowed us to estimate the true effective wavelengths of the system and pointed to the necessity of a proper flux calibration. In the following sections we describe our sets of standards, the adopted magnitudes, and the derived characteristics of the San Pedro Mártir (OAN) *JHK* photometric system as compared with other known photometric systems.

2. Infrared Atmospheric Extinction at San Pedro Mártir

Extinction determinations on a large number of nights have led us to conclude that the extinction coefficients for San Pedro Mártir, B.C. (México) are smaller than those of La Silla (Chile). Furthermore, the photometric stability of the site is such that the adoption of mean extinction coefficients is adequate since the seasonal variations (spring, fall, and winter) turned out to be smaller than the errors in the determination of those coefficients. However, the monsoon season (summer) has not been extensively covered by our observing runs and, consequently, our data for this season are less reliable.

Our determination of the mean extinction coefficients in the air-mass range [1,3] for the San Pedro Mártir Observatory yields the following values.

$$\langle E_J \rangle = 0\overset{m}{.}0918 \pm 0.0048/\text{air mass}$$

$$\langle E_H \rangle = 0\overset{m}{.}0315 \pm 0.0045/\text{air mass}$$

$$\langle E_K \rangle = 0\overset{m}{.}0449 \pm 0.0045/\text{air mass}$$

These values are in good agreement with those expected for a dry site (Manduca & Bell 1979).

3. Standard Stars

The sample of initial candidates for standardization has been monitored systematically during the last five years. A natural photometric system has been developed taking Vega as the primary standard and adopting for it $J = H = K = 0.00$ mag. Observations of Vega were carried out using a special nonsaturating technique that involves a precise calibration of the various preamplifier gains. This procedure allows us to observe Vega and the standard stars reported here with the same lock-in amplifier setup. We estimate that the maximum error introduced by this special procedure is ~ 0.001 mag, which is negligible compared with other error sources.

In Table 1 we present the natural mean "*JHK*" magnitudes of the San Pedro Mártir (OAN) revised set of standard stars. Columns (1), (2), (3), and (4) contain the H-R number, coordinates (1950), and *V* magnitude, respectively. The *JHK* magnitudes are given in columns (5), (7), and (9), respectively, while dispersion values around the mean for each star are listed in columns (6), (8), and (10). Finally, the number of individual observations is given in column (11). The dispersion values represent maximum variability amplitudes for the time period observed, and we have retained as standards only stars whose possible variability is smaller than 3%. The probable error of the mean of our measurements can be calculated from the quotient of these dispersion values to the square root of the number of measurements.

4. Comparison with Other Photometric Systems

Our standard values have been compared with photometric systems adopted at other observatories. In particular we have compared and obtained transformation equations to the AAO, CIT, and ESO systems from the subsamples of standard stars, common to the various sets. These subsamples have been complemented by measuring in our system a few extra objects, adopted as standards by other groups; our photometry for those stars is presented in Table 2. Except for column (1), which lists the stellar designations, columns in this table are the same as in Table 1.

4.1 *Effective Wavelengths for the OAN JHK System*

The characteristics of the San Pedro Mártir (OAN) photometric system have been partially reported by Roth et al. 1984. However, the effective wavelength in a given bandpass is the result of a combination of the transmission of the filter at the operating temperature, the transmission of the atmosphere at the site, the reflectivity of mirrors and dichroics, the detector response, and, finally, the spectral energy distribution of the object that is to be measured. Since we ignored several of these parameters for our system, and in the absence of proper IR laboratory facilities to have determined them, we estimate preliminarily our effective wavelengths for a star whose colors are $(J-K) = (H-K) = 0.0$ (Vega), in an indirect manner. This is accomplished by comparing with other, properly characterized photometric systems, the behavior of our natural magnitudes as a function of color. Such comparison is summarized by the color equations that follow and is also presented graphically in Figures 1 to 3, along with the regression lines of the data points. The errors in the coefficients of the color equations are also included.

4.1.1 *Comparison with the CIT system (Elias et al. 1982, 1983)*

$$J_{\rm CIT} - J_{\rm OAN} = 0.0377\,(\pm 0.0060) - 0.0982\,(\pm 0.0101)\,(J-K)_{\rm OAN}$$

$$H_{\rm CIT} - H_{\rm OAN} = 0.0194\,(\pm 0.0055) - 0.0343\,(\pm 0.0096)\,(J-K)_{\rm OAN}$$

$$K_{\rm CIT} - K_{\rm OAN} = 0.0021\,(\pm 0.0052) + 0.0056\,(\pm 0.0089)\,(J-K)_{\rm OAN}$$

TABLE 1

Natural Mean JHK Magnitudes of the San Pedro Mártir (OAN) Revised Set of Standard Stars

NAME HR	RA (1950)	DEC	V	J	σ_J	H	σ_H	K	σ_K	N_{Obs}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
0027	00 07 42.8	45 47 38	4.50	4.082	0.014	3.858	0.011	3.805	0.013	16
0039	0010395	14 50 19	2.84	3.310	0.021	3.421	0.011	3.497	0.004	13
0088	02 20 19.0	-12 29 14	5.50	5.224	0.013	4.932	0.009	4.890	0.010	9
0718	02 25 29.9	08 14 12	4.29	4.310	0.015	4.353	0.018	4.371	0.019	15
1142	03 41 54.1	23 57 26	4.00	3.834	0.020	3.880	0.018	3.921	0.016	20
1239	03 57 54.3	12 21 01	3.41	3.556	0.022	3.612	0.009	3.634	0.021	9
1552	04 48 32.4	05 31 15	3.69	3.972	0.015	4.066	0.020	4.134	0.020	17
1790	05 22 26.8	06 18 21	1.64	2.064	0.019	2.173	0.014	2.289	0.022	6
1899	05 32 59.1	-05 56 25	3.20	3.265	0.027	3.365	0.011	3.456	0.022	16
3095	07 54 09.1	15 55 30	4.00	3.655	0.030	3.017	0.010	2.915	0.030	8
3314	08 23 09.7	-03 44 31	3.90	3.866	0.021	3.896	0.021	3.917	0.016	33
3779	09 29 16.9	09 59 24	3.00	2.762	0.007	2.042	0.013	1.936	0.011	6
3790	05 22 26.8	06 18 21	1.64	2.064	0.019	2.173	0.014	2.289	0.022	6
3982	10 05 42.3	12 12 46	1.35	1.534	0.017	1.548	0.018	1.581	0.016	10
4030	10 13 45.8	23 45 11	5.00	4.750	0.011	4.432	0.014	4.396	0.014	18
4127	10 29 31.6	14 23 42	2.50	2.180	0.012	1.302	0.009	1.078	0.016	6
4133	10 30 10.7	09 33 54	3.85	4.128	0.025	4.185	0.028	4.228	0.024	35
4550	11 50 18.7	38 01 06	5.20	4.911	0.014	4.460	0.018	4.402	0.014	15
4689	12 17 20.7	-00 23 17	3.89	3.744	0.020	3.747	0.014	3.785	0.014	19
4883	12 49 14.9	27 48 46	3.90	3.722	0.024	3.402	0.015	3.351	0.019	44
4983	13 09 30.2	28 09 26	3.70	3.211	0.013	2.928	0.013	2.893	0.016	19
5384	14 20 42.3	01 28 13	6.27	5.049	0.025	4.717	0.022	4.687	0.017	26
5447	14 32 30.7	29 57 47	4.47	3.682	0.024	3.516	0.016	3.492	0.012	15
6228	16 43 25.7	08 40 21	5.15	2.408	0.014	1.644	0.016	1.464	0.018	10
7001	18 35 15.0	38 38 44	0.03	0.000	0.003	0.000	0.003	0.000	0.003	
7446	19 34 12.0	-07 08 23	5.07	4.947	0.016	4.982	0.015	5.023	0.017	38
7847	20 29 05.1	36 45 58	4.50	4.102	0.012	3.726	0.014	3.570	0.015	28
7950	20 44 58.3	-09 40 50	3.77	3.681	0.015	3.679	0.013	3.686	0.016	19
8143	21 15 27.0	39 11 03	4.23	3.852	0.020	3.805	0.016	3.777	0.017	21
8430	22 04 41.6	25 06 01	3.76	2.902	0.017	2.672	0.015	2.623	0.016	17
8541	22 22 29.1	49 13 20	4.54	4.273	0.010	4.260	0.010	4.246	0.011	27
8551	22 25 19.9	04 26 27	4.79	2.965	0.014	2.409	0.014	2.313	0.014	10
8622	22 37 00.7	38 47 21	5.78	5.316	0.012	5.438	0.013	5.527	0.013	22
8781	23 02 16.2	14 56 06	2.48	2.495	0.014	2.516	0.012	2.520	0.012	10

TABLE 2

Natural Mean JHK Magnitudes of Additional Standard Stars Observed at San Pedro Mártir Observatory (OAN Photometric System)

NAME	RA (1950)	DEC	V	J	σ_J	H	σ_H	K	σ_K	N_{Obs}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
2318	06 20 51	-28 43 00	6.24	5.199	0.020	4.900	0.020	4.900	0.020	2
106965	12 15 24	01 51 10		7.321	0.020	7.298	0.020	7.318	0.020	2
129655	14 41 11	-02 17 38		6.773	0.020	6.693	0.020	6.667	0.020	2
5530	14 45 09	-15 35 00	5.16	4.339	0.020	4.143	0.020	4.119	0.020	2
BD+3°2954	14 52 23	03 11 33		5.893	0.020	4.985	0.020	4.778	0.020	2
BD+2°2957	15 22 29	01 41 06		5.253	0.020	4.431	0.020	4.238	0.020	2
5996	16 01 29	-13 48 00	6.31	5.176	0.020	4.907	0.020	4.829	0.020	1
S-R3	16 23 07	-24 27 26		7.782	0.020	6.998	0.020	6.506	0.020	2
6175	16 34 24.1	-10 28 02	2.50	2.548	0.016	2.577	0.019	2.633	0.019	6
7773	20 15 07	-13 04 00	4.75	4.763	0.020	4.807	0.020	4.840	0.020	1

4.1.2 *Comparison with the AAO System (Allen & Cragg 1983)*

$$J_{AAO} - J_{OAN} = 0.0591\,(\pm 0.0051) - 0.0092\,(\pm 0.0123)\,(J-K)_{OAN}$$

$$H_{AAO} - H_{OAN} = 0.0331\,(\pm 0.0043) - 0.0449\,(\pm 0.0103)\,(J-K)_{OAN}$$

$$K_{AAO} - K_{OAN} = 0.0162\,(\pm 0.0062) - 0.0102\,(\pm 0.0151)\,(J-K)_{OAN}$$

4.1.3 *Comparison with the ESO System (Engels et al. 1981; Wamsteker 1981)*

$$J_{ESO} - J_{OAN} = 0.0720\,(\pm 0.0059) - 0.0542\,(\pm 0.0218)\,(J-K)_{OAN}$$

$$H_{ESO} - H_{OAN} = 0.0599\,(\pm 0.0072) - 0.0179\,(\pm 0.0263)\,(J-K)_{OAN}$$

$$K_{ESO} - K_{OAN} = 0.0298\,(\pm 0.0046) - 0.0133\,(\pm 0.0172)\,(J-K)_{OAN}$$

The residuals for the photometric differences described above are presented in graphical form in Figures 4 to 6. In Figure 7 we have also included the comparison of our measurements with those published by Tapia et al. 1986, hereafter TNR. From these figures, we can judge the photometric quality of the various data sets, the combined errors of ours and those of AAO and CIT being less than 1.5%, while for ESO and TNR being 2.2% and 5%, respectively.

It is worth noticing that some of the TNR stars deviate by almost 10% from our measurements. We do not fully understand the origin of such discrepancies since in principle those stars are not variables of such large amplitudes. As the instrumental setup is the same, we suspect problems arising from the amplifier calibration procedures followed by Tapia et al. 1986. In Figures 8 to 11 we present the histograms of the distribution functions of the residuals for the differences described by the above color equations for comparison of the OAN system (this paper) with other systems and observers.

From the color dependence of the differences between other photometric systems and ours, we may conclude that:

(1) The J_{OAN} bandpass is essentially identical to the J_{AAO} bandpass. Hence, we adopt $\lambda_{eff} = 1.198$ μm for Vega in this filter, the value calculated by Bessell & Brett 1988.

(2) The H_{OAN} bandpass does resemble H_{ESO}. Hence, the effective wavelength for it should be $\lambda_{eff} = 1.58$ μm (Bessell & Brett 1988).

(3) The K_{OAN} bandpass is essentially identical to the K_{CIT} and K_{AAO} ones. In this case we adopt $\lambda_{eff} = 2.21$ μm for this filter, the average of the values determined for those systems by Bessell & Brett 1988.

4.2 *Absolute Flux Calibration of the OAN JHK System*

The fluxes corresponding to zero magnitude are calculated from the observed fluxes of Vega by Strecker, Erikson & Witteborn 1979, interpolated to the effective wavelengths given above for our system, adopting the Vega model atmosphere of Dreiling & Bell 1980. The fluxes at 2.21 μm have been supplemented by absolute-flux determinations of Blackwell, Petford & Shallis 1980, Blackwell et al. 1983, Selby et al. 1983, and Booth et al. 1989. The absolute calibration fluxes ($m = 0$) of the OAN *JHK* system

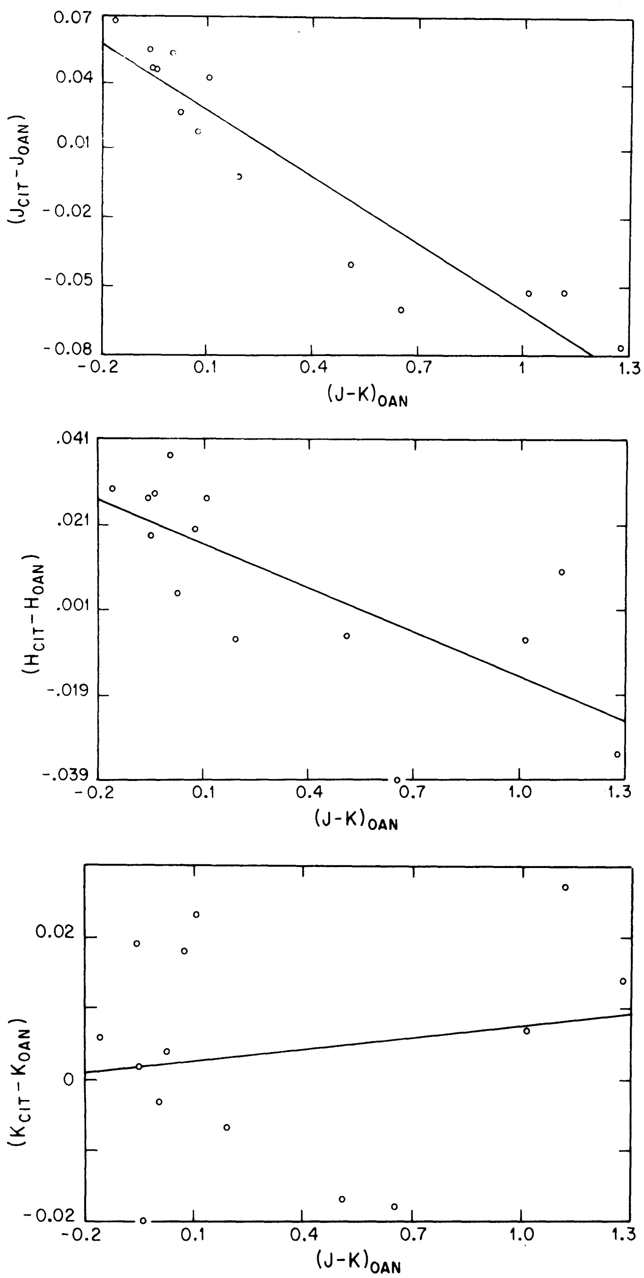

FIG. 1–Comparison of the behavior of the natural magnitudes for the standard stars in common, as a function of color for the CIT (Elias et al. 1982, 1983) and OAN (this paper) photometric systems. Regression lines for the data (see text) are also plotted. (a) ($J_{\rm CIT} - J_{\rm OAN}$ versus $(J-K)_{\rm OAN}$; (b) ($H_{\rm CIT} - H_{\rm OAN}$) versus $(J-K)_{\rm OAN}$; and (c) ($K_{\rm CIT} - K_{\rm OAN}$) versus $(J-K)_{\rm OAN}$.

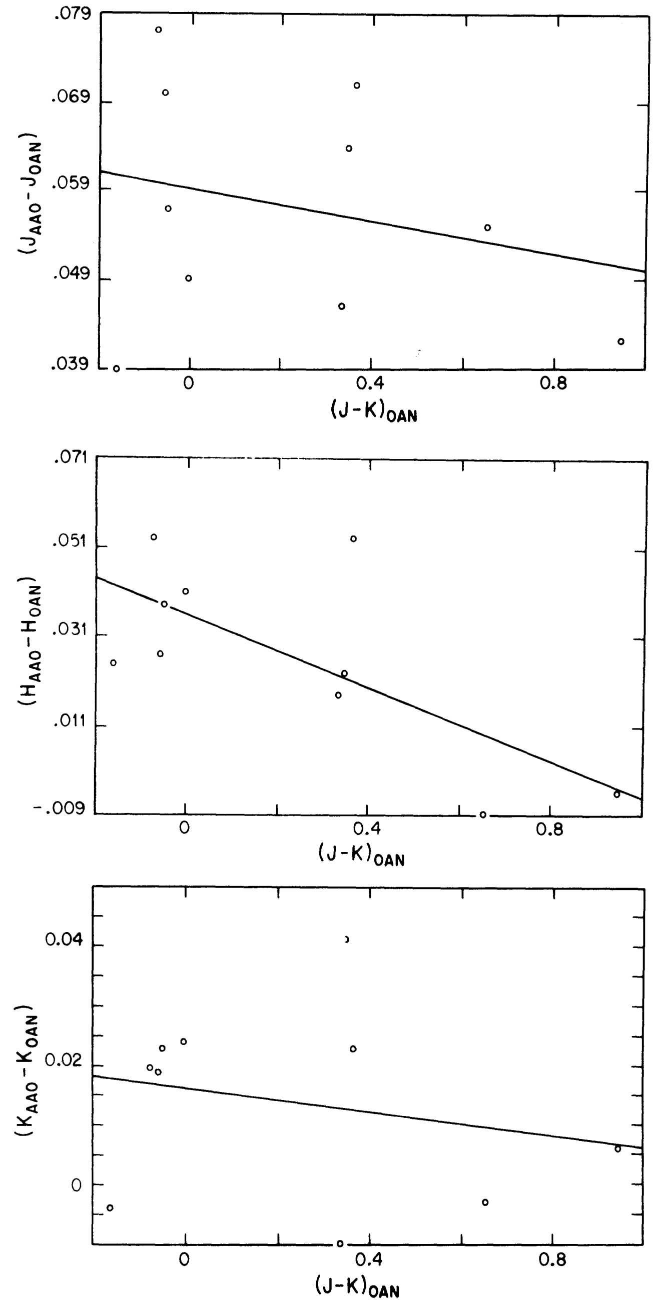

FIG. 2–Comparison of the behavior of the natural magnitudes for the standard stars in common, as a function of color for the AAO (Allen & Cragg 1983) and OAN (this paper) photometric systems. Regression lines for the data (see text) are also plotted. (a) ($J_{\rm AAO} - J_{\rm OAN}$) versus $(J-K)_{\rm OAN}$; (b) ($H_{\rm AAO} - H_{\rm OAN}$) versus $(J-K)_{\rm OAN}$; and (c) ($K_{\rm AAO} - K_{\rm OAN}$) versus $(J-K)_{\rm OAN}$.

are presented in Table 3. These absolute fluxes are probably precise to 5%, when all sources of error are considered. This figure essentially reflects the dispersion in the values reported in the literature of the measurements of Vega as confronted with a standard source.

4.3 *Transformation Equations*

From the common samples with CIT (Elias et al. 1982, 1983), AAO (Allen & Cragg 1983), and ESO (Engels et al. 1981), we have derived transformation equations for the OAN photometric system. Our results are as follows.

4.3.1 *Transformation Equations to the CIT System*

$$K_{\rm CIT} = -0.0176\,(\pm 0.0141) + 1.0047\,(\pm 0.0030)\,K_{\rm OAN}$$

$$(J-K)_{\rm CIT} = 0.0356\,(\pm 0.0048) + 0.8962\,(\pm 0.0083)\,(J-K)_{\rm OAN}$$

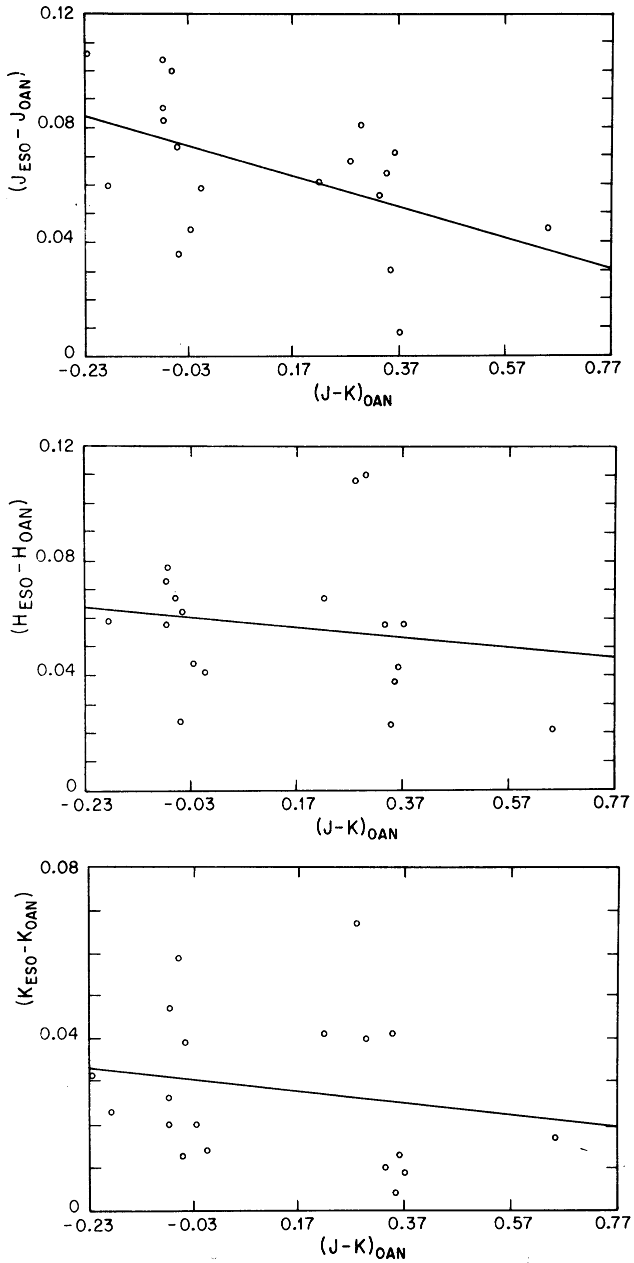

FIG. 3–Comparison of the behavior of the natural magnitudes for the standard stars in common, as a function of color for the ESO (Engels et al. 1981; Wamsteker 1981; Koornneef 1983) and OAN (this paper) photometric systems. Regression lines for the data (see text) are also plotted. (a) $(J_{\rm ESO} - J_{\rm OAN})$ versus $(J-K)_{\rm OAN}$; (b) $(H_{\rm ESO} - H_{\rm OAN})$ versus $(J-K)_{\rm OAN}$; and (c) $(K_{\rm ESO} - K_{\rm OAN})$ versus $(J-K)_{\rm OAN}$.

$$(H-K)_{\rm CIT} = 0.0138\,(\pm 0.0042) + 0.8593\,(\pm 0.0264)\,(H-K)_{\rm OAN}$$

4.3.2 *Transformation Equations to the AAO System*

$$K_{\rm AAO} = -0.0044\,(\pm 0.0186) + 1.0047\,(\pm 0.0046)\,K_{\rm OAN}$$

$$(J-K)_{\rm AAO} = 0.0429\,(\pm 0.0052) + 1.0010\,(\pm 0.0126)\,(J-K)_{\rm OAN}$$

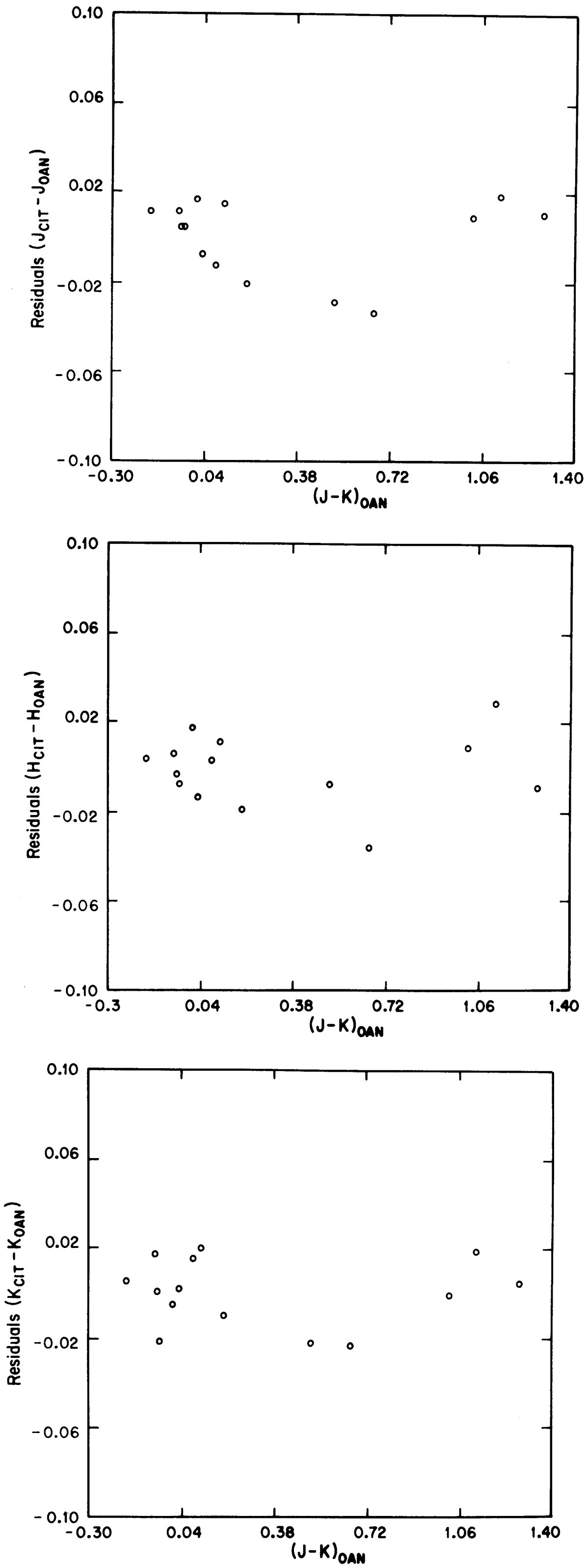

FIG. 4–Residuals of the comparison of the CIT standard-star IR photometric system (Elias et al. 1982, 1983) with the OAN system (this paper), for the *JHK* photometric bands. (a) Residuals of $(J_{\rm CIT} - J_{\rm OAN})$ versus $(J-K)_{\rm OAN}$; (b) residuals of $(H_{\rm CIT} - H_{\rm OAN})$ versus $(J-K)_{\rm OAN}$; and (c) residuals of $(K_{\rm CIT} - K_{\rm OAN})$ versus $(J-K)_{\rm OAN}$.

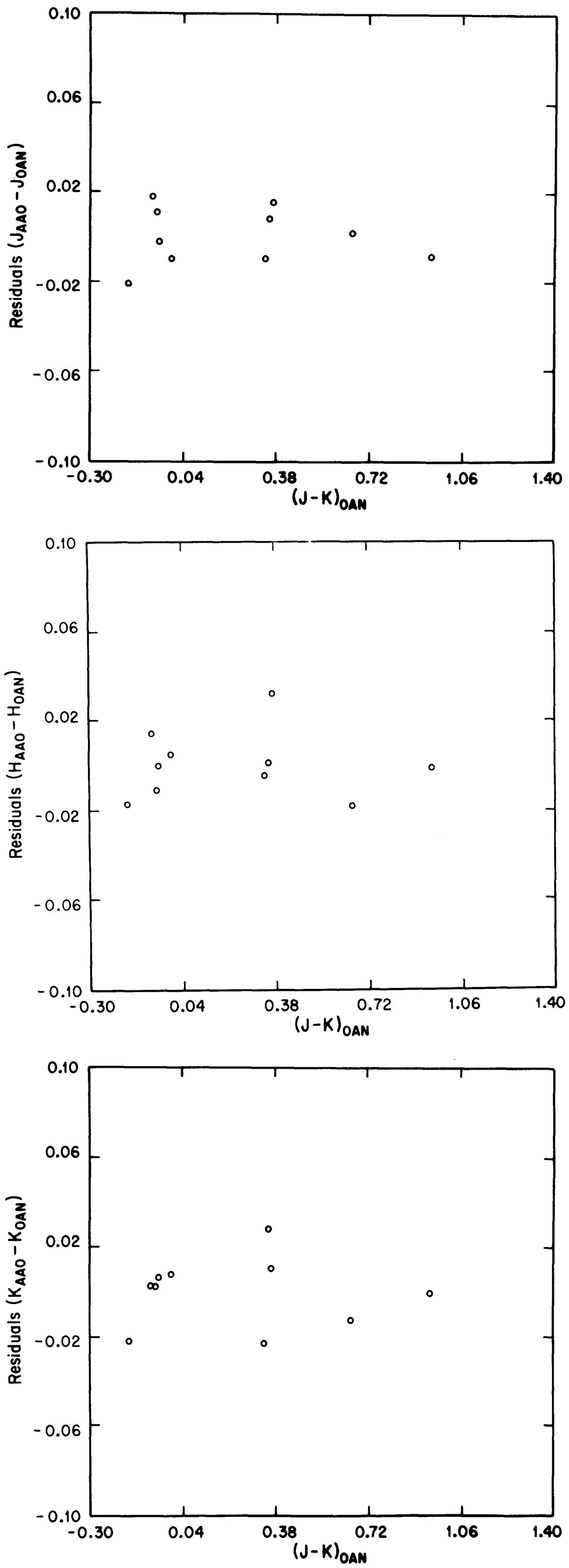

FIG. 5–Residuals of the comparison of the AAO standard-star IR photometric system (Allen & Cragg 1983) with the OAN system (this paper) for the *JHK* photometric bands. (a) Residuals of ($J_{AAO} - J_{OAN}$) versus $(J-K)_{OAN}$; (b) residuals of ($H_{AAO} - H_{OAN}$) versus $(J-K)_{OAN}$; and (c) residuals of ($K_{AAO} - K_{OAN}$) versus $(J-K)_{OAN}$.

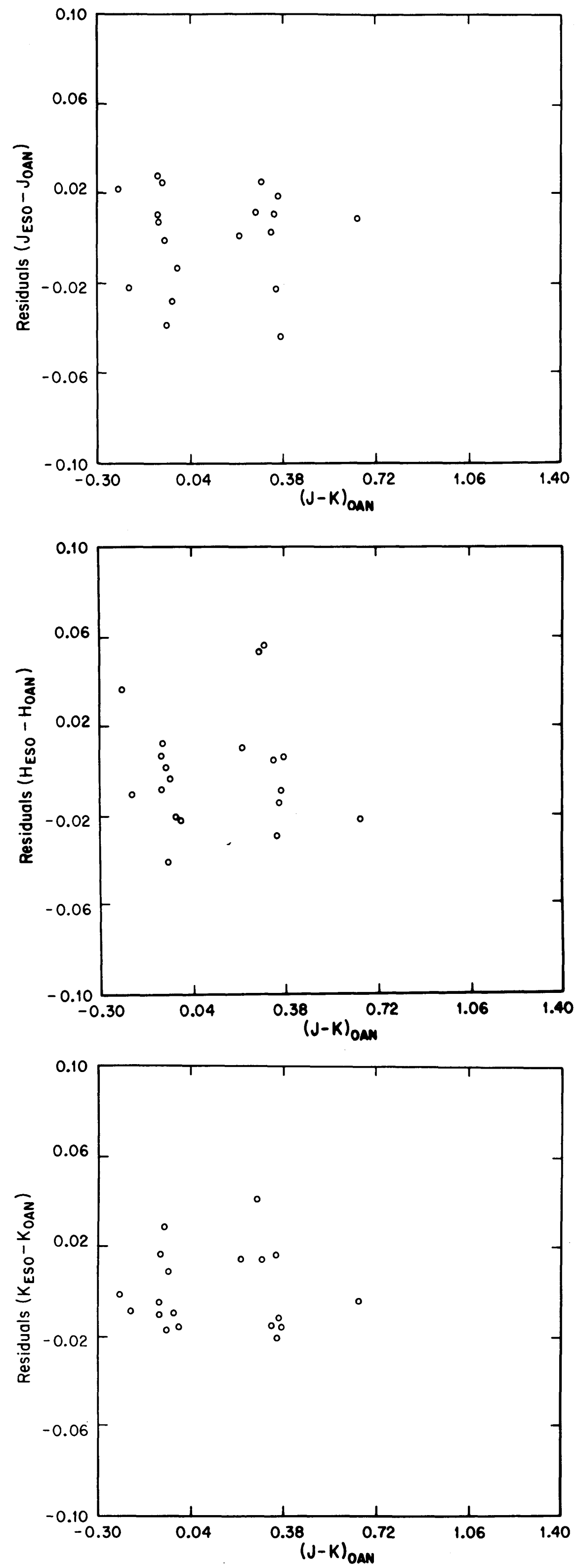

FIG. 6–Residuals of the comparison of the ESO standard-star IR photometric system (Engels et al. 1981; Wamsteker 1981) with the OAN system (this paper) for the *JHK* photometric bands. (a) Residuals of ($J_{AAO} - J_{OAN}$) versus $(J-K)_{OAN}$; (b) residuals of ($H_{AAO} - H_{OAN}$) versus $(J-K)_{OAN}$; and (c) residuals of ($K_{AAO} - K_{OAN}$) versus $(J-K)_{OAN}$.

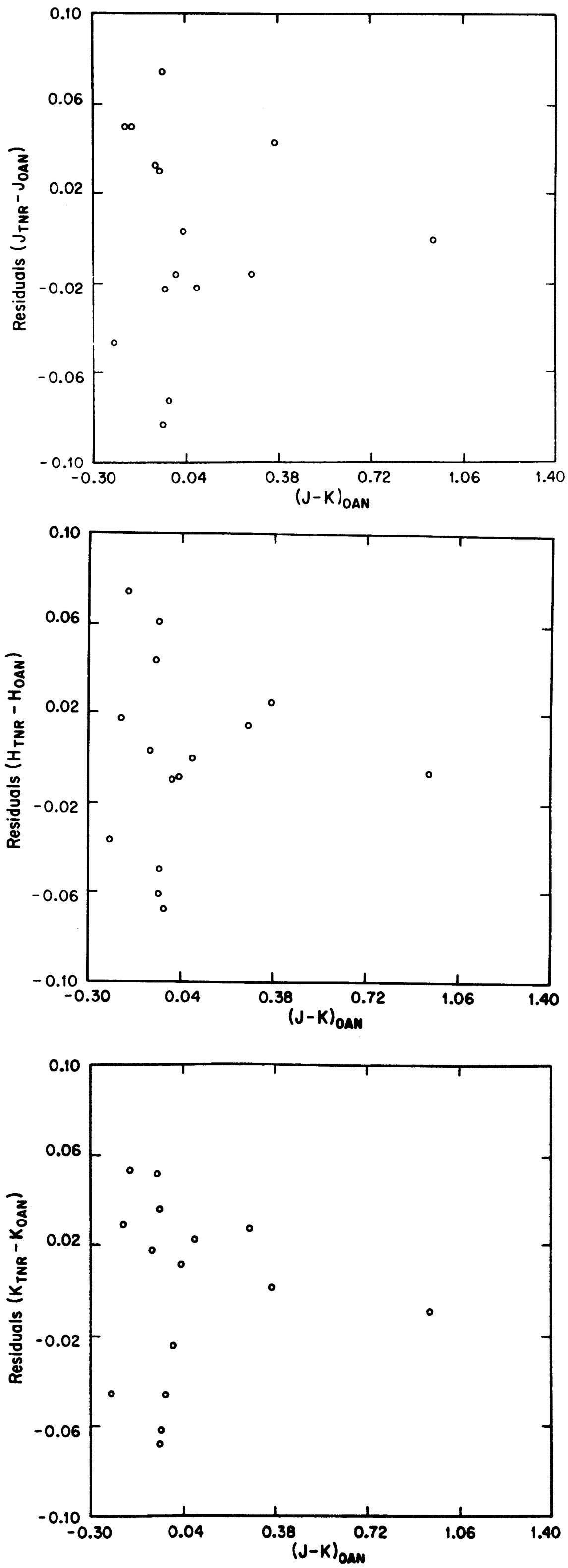

FIG. 7–Residuals of the comparison of the TNR (Tapia et al. 1986) standard-star IR measurements as published, with the OAN system (this paper), for the *JHK* photometric bands. (a) Residuals of $(J_{\rm TNR} - J_{\rm OAN})$ versus $(J-K)_{\rm OAN}$; (b) residuals of $(H_{\rm TNR} - H_{\rm OAN})$ versus $(J-K)_{\rm OAN}$; and (c) residuals of $(K_{\rm TNR} - K_{\rm OAN})$ versus $(J-K)_{\rm OAN}$. Differences for this set of data amount to more than 8%.

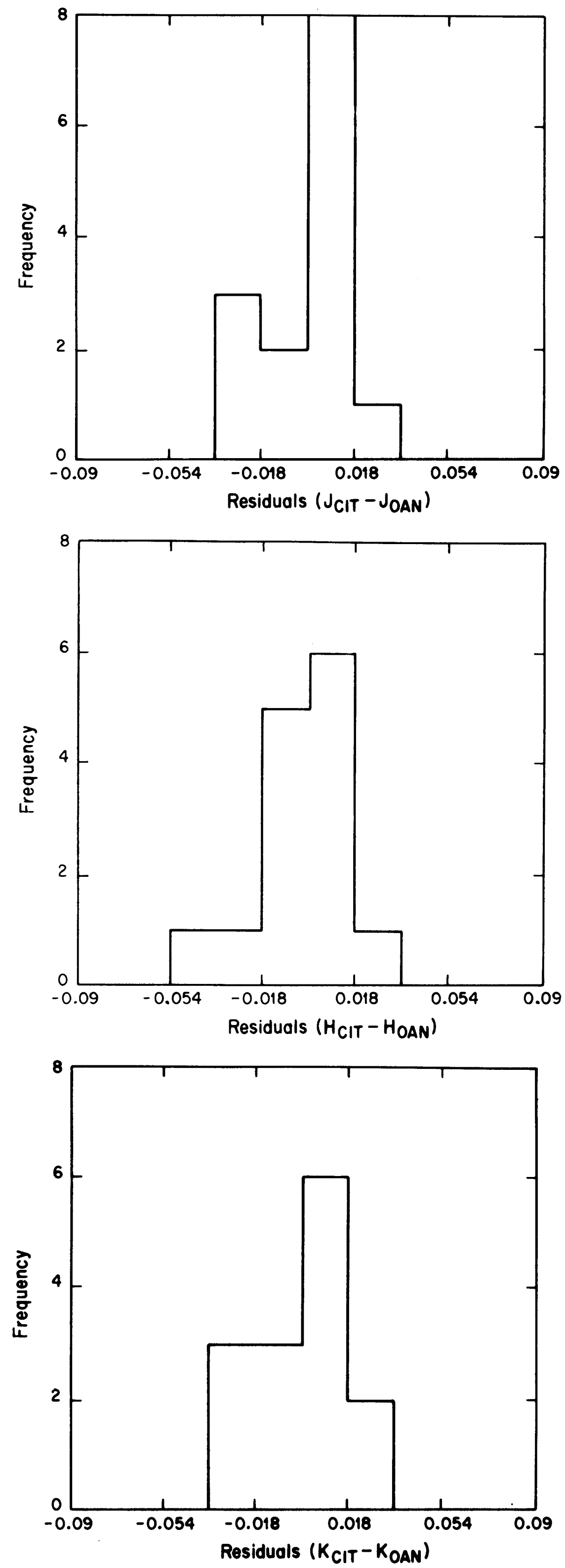

FIG. 8–Frequency histogram of the residuals of standard-star IR measurements of the CIT photometric system (Elias et al. 1982, 1983) with the OAN photometric system (this paper). (a) Residuals of $(J_{\rm CIT} - J_{\rm OAN})$ versus frequency; (b) residuals of $(H_{\rm CIT} - H_{\rm OAN})$ versus frequency; and (c) residuals of $(K_{\rm CIT} - K_{\rm OAN})$ versus frequency.

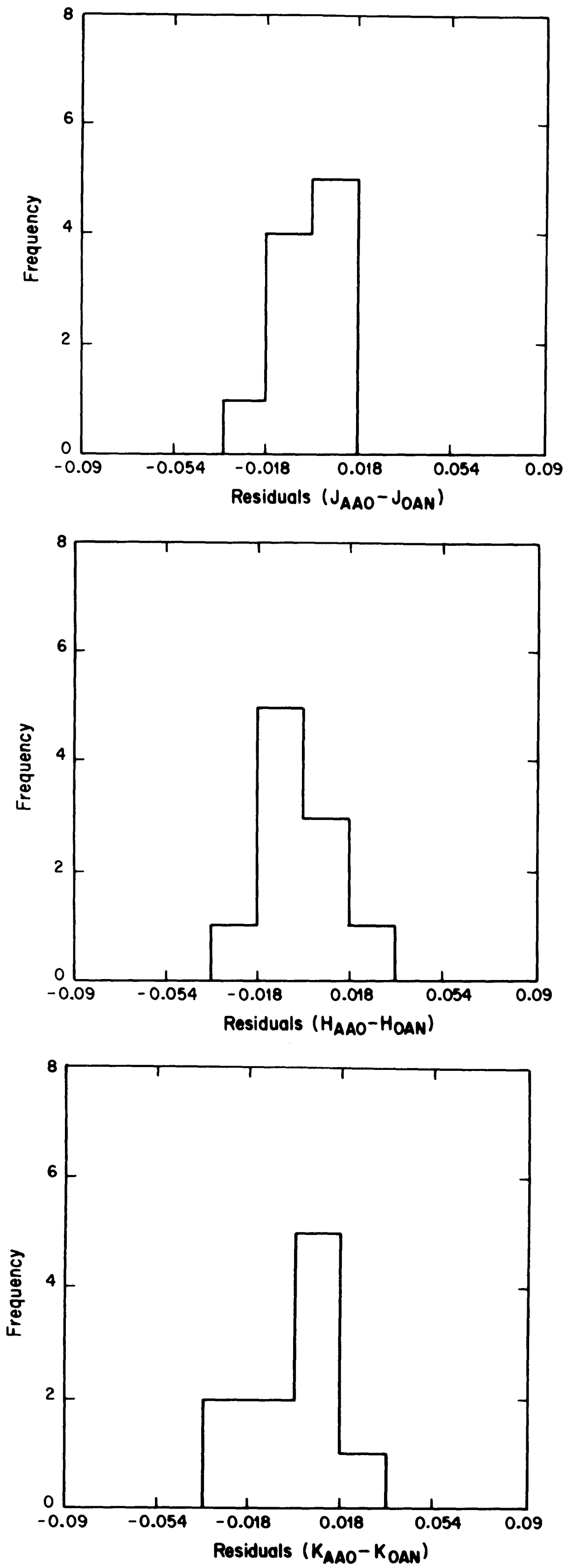

FIG. 9–Frequency histogram of the residuals of standard-star IR measurements of the AAO photometric system (Allen & Cragg 1983) with the OAN photometric system (this paper). (a) Residuals of ($J_{\mathrm{AAO}} - J_{\mathrm{OAN}}$) versus frequency; (b) residuals of ($H_{\mathrm{AAO}} - H_{\mathrm{OAN}}$) versus frequency; and (c) residuals of ($K_{\mathrm{AAO}} - K_{\mathrm{OAN}}$) versus frequency.

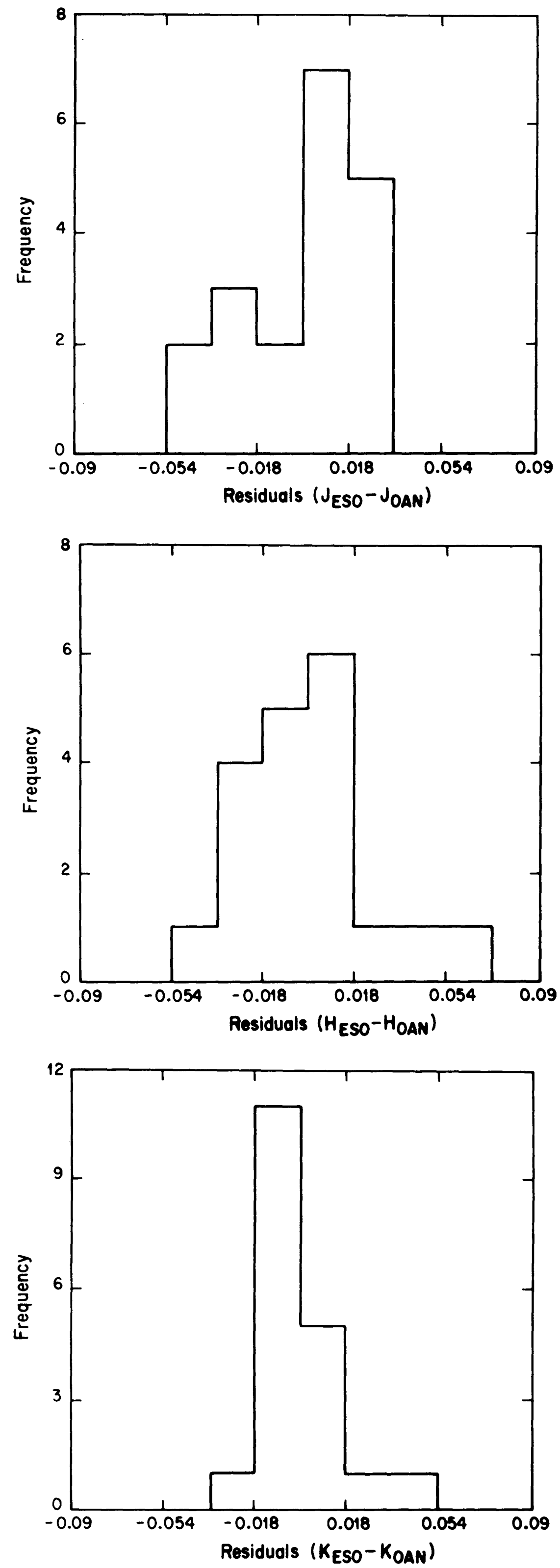

FIG. 10–Frequency histogram of the residuals of standard-star IR measurements of the ESO photometric system (Engels et al. 1981; Wamsteker 1981) with the OAN photometric system (this paper). (a) Residuals of ($J_{\mathrm{ESO}} - J_{\mathrm{OAN}}$) versus frequency; (b) residuals of ($H_{\mathrm{ESO}} - H_{\mathrm{OAN}}$) versus frequency; and (c) residuals of ($K_{\mathrm{ESO}} - K_{\mathrm{OAN}}$) versus frequency.

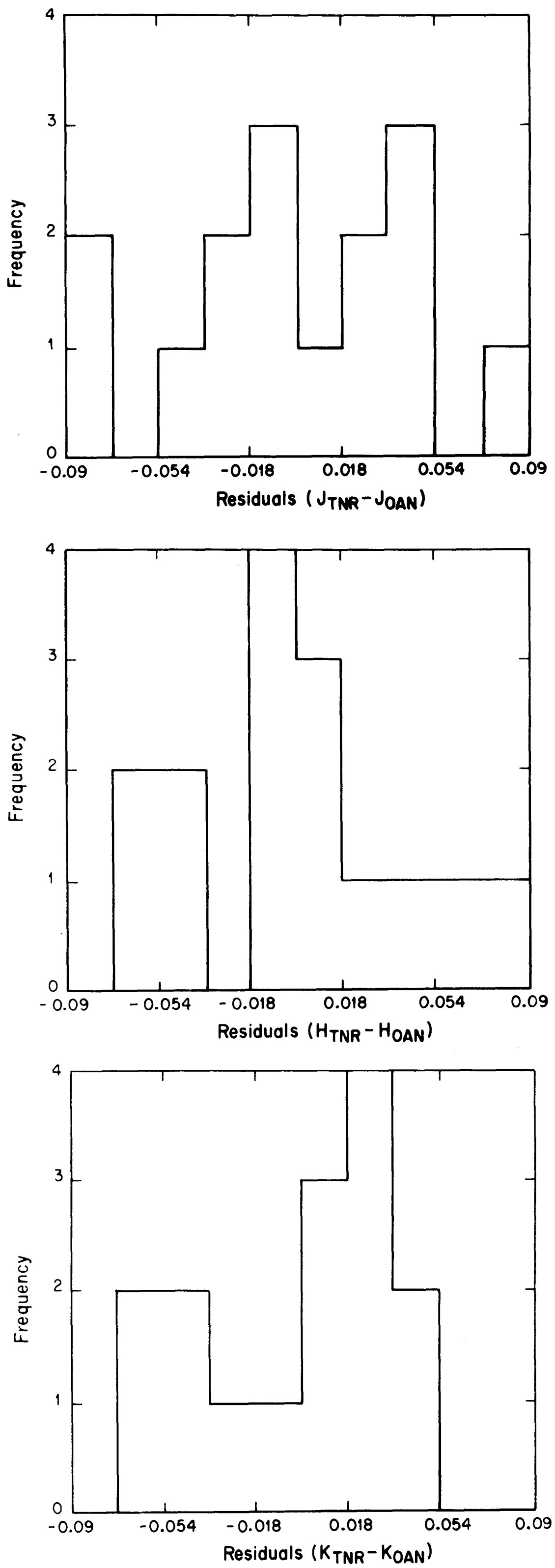

FIG. 11–Frequency histogram of the residuals of the standard-star IR measurements of TNR (Tapia et al. 1986) with the OAN photometric system (this paper). (a) Residuals of ($J_{\rm TNR} - J_{\rm OAN}$) versus frequency; (b) residuals of ($H_{\rm TNR} - H_{\rm OAN}$) versus frequency; and (c) residuals of ($K_{\rm TNR} - K_{\rm OAN}$) versus frequency.

TABLE 3

Absolute Flux Calibration, $m = 0.0$

Bandpass	λ_{eff} (μm)	$F_{\lambda,0}$ ($W/cm^2\mu m$)	$F_{\nu,0}$ (Jy)
J_{OAN}	1.198	3.420×10^{-13}	1642
H_{OAN}	1.580	1.295×10^{-13}	1105
K_{OAN}	2.210	3.920×10^{-14}	632

$$(H-K)_{\rm AAO} = 0.0176\,(\pm 0.0046) + 0.8196\,(\pm 0.0614)\,(H-K)_{\rm OAN}$$

4.3.3 *Transformation Equations to the ESO System*

$$K_{\rm ESO} = 0.0321\,(\pm 0.0157) + 0.9989\,(\pm 0.0040)\,K_{\rm OAN}$$

$$(J-K)_{\rm ESO} = 0.0422\,(\pm 0.0058) + 0.9591\,(\pm 0.0216)\,(J-K)_{\rm OAN}$$

$$(H-K)_{\rm ESO} = 0.0322\,(\pm 0.0047) + 0.8057\,(\pm 0.0922)\,(H-K)_{\rm OAN}$$

These transformation equations, when combined with those of Bessell & Brett 1988, yield average transformation equations to Johnson's photometric system. The resulting equations are

$$K_J = K_{\rm OAN} + 0.029 - 0.011\,(V-K)_{\rm OAN}$$

$$(J-K)_J = 0.038 + 0.974\,(J-K)_{\rm OAN}$$

$$(H-K)_J = 0.014 + 0.834\,(H-K)_{\rm OAN}\ .$$

As is shown above, the comparison to other near-IR photometric systems allowed us to characterize the OAN *JHK* photometric system and the San Pedro Mártir site at near-IR wavelengths. The differences found with the work by TNR who used the same instrumental setup, suggest that their calibration and system characterization must be revised.

5. Conclusions

A set of reliable nonvariable (< 3%) standard stars has been selected from observations carried out during 170 photometric nights distributed in the period of time 1984–89 on the 2.1-m telescope at San Pedro Mártir National Observatory (OAN). These observations allowed us to properly characterize the site and the instrumental system. Our results are summarized as follows:

1. The mean extinction coefficients of the OAN at *JHK* have been determined (see §2).

2. From the color dependence of the differences between other photometric systems and ours, we derive the effective wavelengths for the *JHK* bandpasses: $J_{\rm OAN}$ corresponds to $\lambda_{\rm eff} = 1.198$ μm, $H_{\rm OAN}$ corresponds to $\lambda_{\rm eff} = 1.58$ μm, and $K_{\rm OAN}$ corresponds to $\lambda_{\rm eff} = 2.21$ μm.

3. The absolute calibration for Vega obtained for our *JHK* bandpasses is: $F_{0,J} = 3.420 \times 10^{-13}$ W/cm^2 μm or 1642 Jy; $F_{0,H} = 1.295 \times 10^{-13}$ W/cm^2 μm or 1105 Jy; $F_{0,K} = 3.92 \times 10^{-14}$ W/cm^2 μm or 632 Jy.

4. From the subsamples of standard stars common to CIT (Elias et al. 1982, 1983), AAO (Allen & Cragg 1983), and ESO (Engels et al. 1981) photometric systems, we have derived transformation equations for the OAN IR-photometry.

We very much appreciate the essential support of the technical and administrative staff of the San Pedro Mártir National Observatory. We thank the efficient help of J. Orta and A. García.

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