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Sky conditions for infrared observations at Kavalur

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Abstract. We present the extinction coefficients in the J, H, K near infrared bands derived for Kavalur during the years 1987, 1988 and 1989. Humidity and temperature observations made at Kavalur during these years are used to ascertain the most suitable months for infrared observations. Mean values of the extinction coefficients in the J, H and K bands are $k_J = 0.20$, $k_H = 0.13$ and $k_K = 0.19$ respectively. Absolute humidity at Kavalur is lowest during the months of November, December, January, February and March.

Key words: extinction coefficients—IR bands—humidity—temperature conditions

1. Introduction

Atmospheric constitutents which attenuate IR radiation are many. The three most common gases in the atmosphere namely N_2, O_2 and Argon are almost completely transparent to infrared radiation. Most of the absorption is caused by molecules of water vapour, carbondioxide and ozone. Minor constitutents such as methane, nitrous oxide, carbonmonoxide and isotopic species of water, carbondioxide and ozone make noticeable absorption over long slant paths. Gaseous molecules, solid particles and liquid drops in the atmosphere scatter infrared radiation. All these agencies which cause attenuation in the infrared show appreciable variation in concentration from location to location and over the same location from season to season, depending on the mateorological conditions. One of the most basic requirements for a ground based infrared observatory site is that the above attenuation be low and not show large night-to-night variations. The photometric quality of the site is very closely linked with the humidity and temperature observed at the site and their seasonal variations. The undisturbed atmosphere above an inversion layer characterized by low relative humidity and very little temperature changes during night would provide excellent seeing conditions.

The Kavalur site where the Vainu Bappu Observatory is located is a low-altitude site (height 700 m). The place is moist by infrared standards and experiences large variations in precipitable water content during many months in a year. Here, we present the results on the extinction coefficients in the J, H, K bands derived from our photometric observations carried out over the past three years. We have used these together with the temperature and humidity data to ascertain the most suitable months in a year for infrared observations at Kavalur.

2. Instruments and observations

Atmospheric extinction measurements in the J, H, K bands were made as part of an ongoing program on IR photometry of Be stars started in 1988. The observations were made using the IR photometer system (Shivanandan *et al.* 1987) at the Cassegrain focus of the 102 cm reflector at Kavalur. The photometer has a liquid nitrogen cooled photovoltaic indium antimony detector sensitive to 1-5 μm radiation when maintained at a temperature of 77K. We used the J, H, K 'medium band width' interference filters supplied by the infrared laboratories, USA that isolate the J (1.25 μm), H (1.63 μm) and K (2.25 μm) bands of the Johnson system in the photometer. A focal plane chopper operated at 15 Hz modulated the light received from the Cassegrain optical system of the telescope. Our observations used an angular beam of size 31 arcsec and a beam throw of 60 arcsec. We used a lock-in-amplifier in the analog mode which provided the final output in digitised form and the data were stored on a personal computer operated in an on-line mode.

Each night along with the program stars, one standard star was observed from large to small zenith angles so as to cover large range of airmass in the sequence J, H, K—K, H, J filters. The observed magnitudes of the star in the J, H, K bands were then calculated from the averages of these two sets of observations. Only such sets containing at least 5 to 6 observations for each extinction star observed, have been included in this study. If X is the path length in units of airmass at the zenith of the observer and k the extinction coefficient, then the absolute magnitude m_0 of the star above the atmosphere is related to the observed magnitude m through the relation

$$m_0 = m - kX.$$

A least square fit to the observed values of m and X gives the value of the constant k.

Temperature and humidity at the observing floor within the telescope dome are monitored every night by noting down the readings of a standard thermometer and a calibrated hygrometer four times through the night at 8 pm, 11 pm, 02 am and 05 am. (Indian Standard Time). These data collected for the period 1987 Jan. to 1989 Dec. were also used to judge the favourable season for the IR observations from Kavalur.

3. Results and discussions

3.1. *Temperature and humidity*

Of the three main infrared absorbing constituents in the atmosphere, namely O_3, CO_2 and water vapour, opacity to infrared radiation by O_3 is almost the same at sea level as at high altitudes. CO_2 is somewhat uniformly mixed in the atmosphere, though there are instances showing appreciable differences in its amount in different air masses. The amount of water vapour on the other hand shows large variations and critically depends upon the altitude as well as on the meteorological conditions prevailing over the site. Hence a good knowledge of the humidity and temperature conditions is essential to judge the suitability of a site for IR observations. The plots of the night time temperature and the percentage relative humidity (mean of the 4 values recorded at 8 pm, 11 pm, 2 am and 5 am every night) for the period 1987 Jan. to 1989 Dec. are presented in figure 1. Hottest nights are in the month of May (27.5°C) and the coolest nights are in December and January when the mean night time temperature drops down to 19.7°C. Relative humidity at Kavalur is generally higher than 50% (figure 1b). The lowest values recorded are in the months of February, March and April when the night starts with relative humidity of 30 to 40% and steadily increases to 80 to 90% towards the morning hours. On some

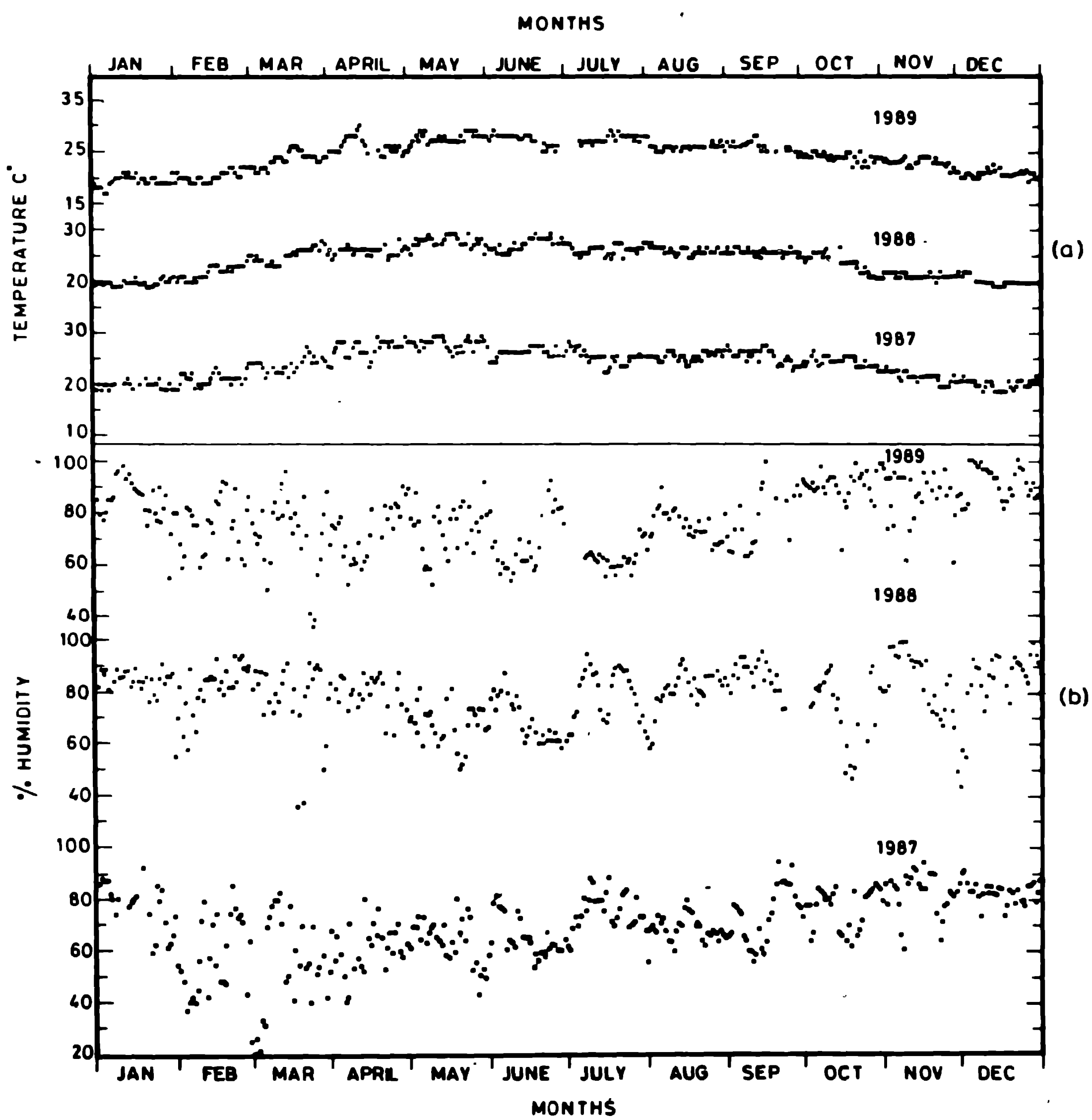

Figure 1. Daily night-time values of the meteorological parameters (a: temperature; b: percentage relative humidity) at the observing floor of the 102 cm reflector dome during the period 1987 Jan. to 1989 Dec. The daily values are the means of the recorded values at 8 pm, 11 pm, 2 am and 5 am (Indian Standard Time).

occasions the relative humidity rose beyond 90% resulting in the formation of ground fog.

The dry bulb temperature and relative humidity values obtained each night have been used to calculate the mean absolute humidity for the night using the relation:

$$\chi = 2.17 \cdot l_s \ R_H \ T^1$$

where χ is the absolute humidity in gm/m^3; l_s the saturation vapour pressure in millibars; R_H the relative humdity in percent near the ground, and T the surface temperature in degree K.

The values of l_s were borrowed from the table prepared by the Indian Meteorological Department. The mean absolute humidity given for each night in figure 2a is the mean of four observations made during the night. The differences in absolute humidity recorded at 8 pm and 5 am each night were used to represent the humidity variation over the night. These variations obtained for the 3 year period are plotted in

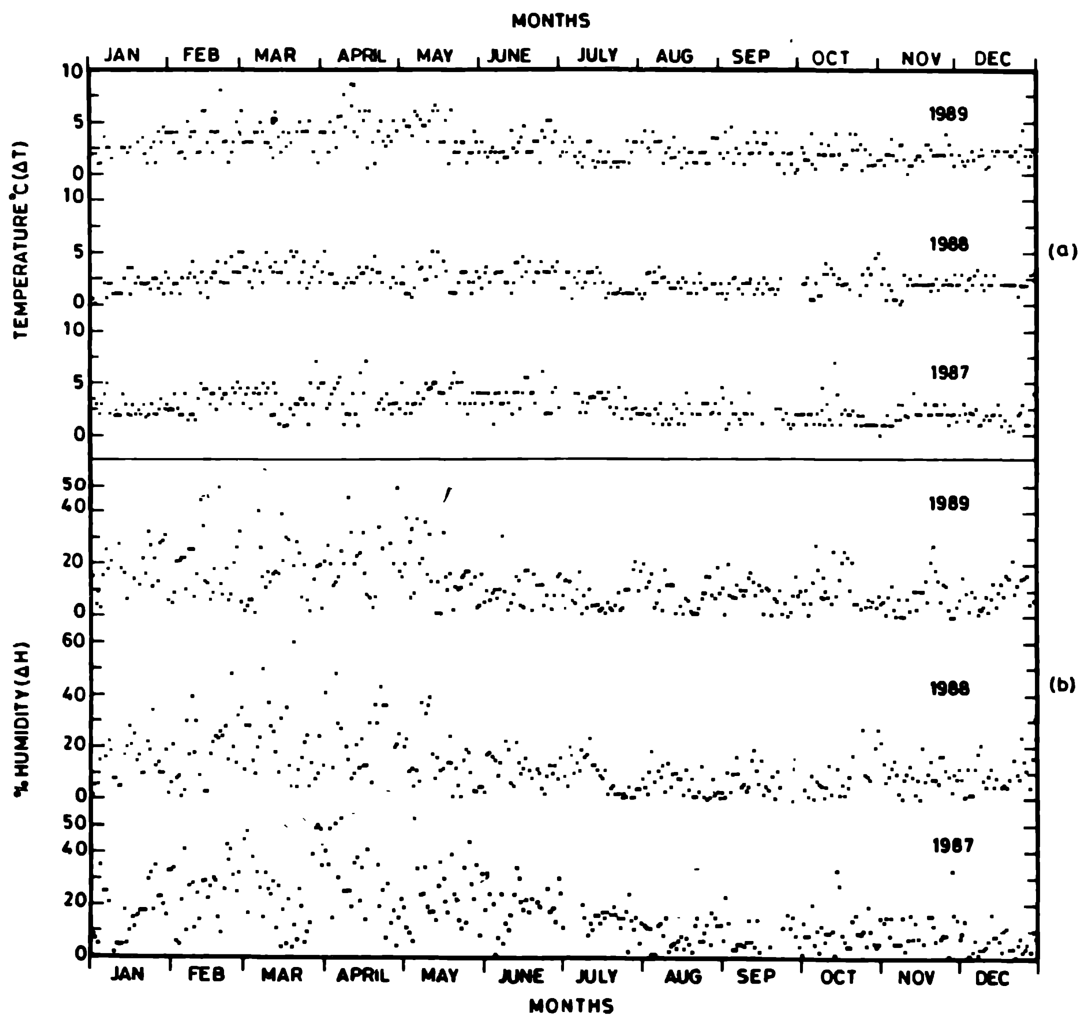

Figure 2. Mean daily night time values of (a) mean absolute humidity (mean of the values for 8 pm, 11 pm, 2 am and 5 am), and (b) variation of absolute humidity between dusk and dawn at the observing floor of the 102 cm reflector during the period 1987 Jan. to 1989 Dec.

figure 2b. We present in figure 3a the monthly means of the absolute humidity and in figure 3b the variation in the absolute humidity during the same night both averaged over the 3 year period. From figures 2 and 3 it can be seen that the mean absolute humidity at Kavalur varies over a wide range from 4 gms m^{-3} to 20 gms m^{-3}, whereas its variation during the same night (except during the months of March, April and May) is only around 2 gms m^{-3}. Accuracy in IR photometry is dependent more on this variation rather than the absolute value of the absolute humidity at the place. Figure 3a shows that the absolute humidity is lowest during the months of November, December, January, February and March. These are also the months when the nightly variation in absolute humidity is low and when Kavalur has the maximum number of clear photometric observing hours (figure 4). Considering these factors one can conclude that November to March are the favourable months for IR observations at Kavalur. It is interesting to note that Bhatt and Mahra (1987) from water vapour measurements at the Manora Peak site at Naini Tal concluded that the same period (winter months of November to March) is most suitable, for IR observations there.

Usually the absolute humidity at a place increases during the night with the fall in temperatur. Measurements of Bhatt & Mahra (1987) at the Manora Peak were made during the day time (11 am and 2 pm) when the ground radiates and the distribution of

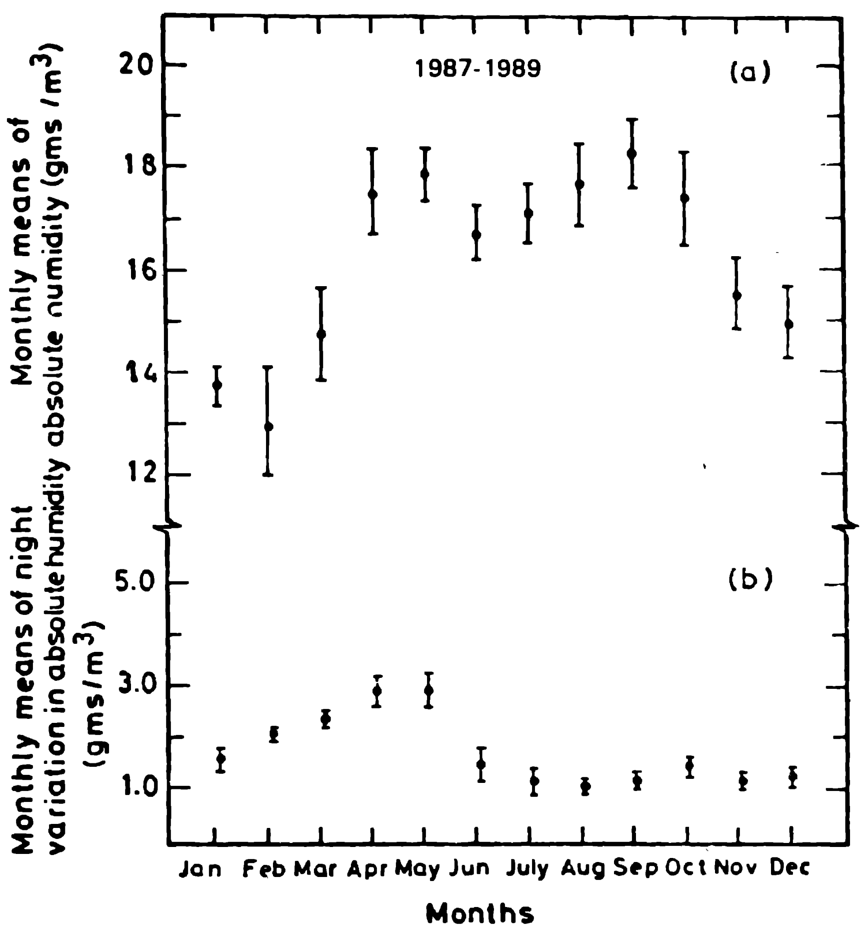

Figure 3. Plot of (a) monthly mean of absolute humidity, and (b) monthly mean of the variation of absolute humidity between dusk and dawn.

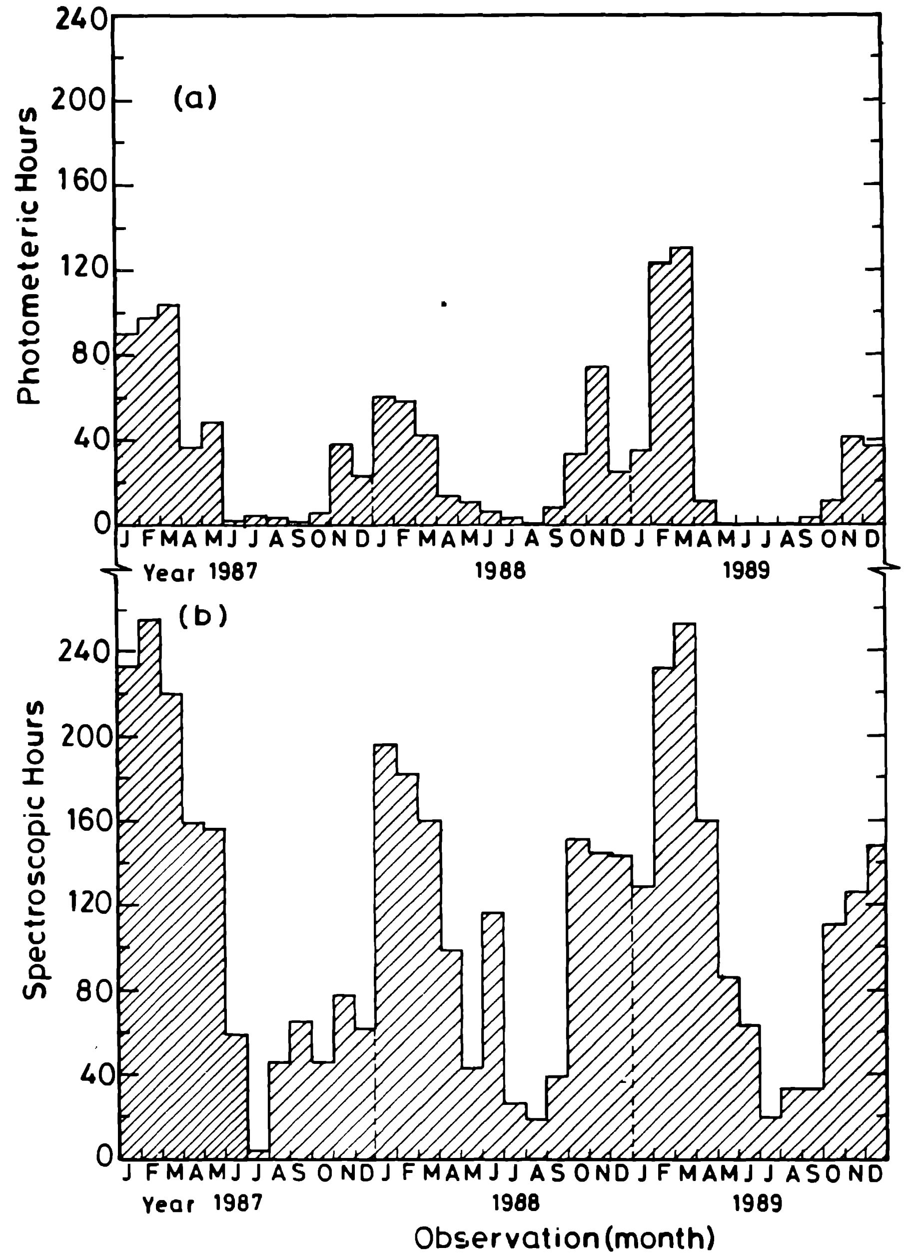

Figure 4. The number of spectroscopic and photometric hours available for observations each month at Kavalur for the three year period 1987 Jan. to 1989 Dec.

water vapour with height above the ground is different from its night time distribution. Thus the correlation betwen the precipitable water vapour and the absolute humidity is bound to be different during day and night. But even after making some allowance for the increase in absolute humidity at night, it is seen that the water vapour content in the atmosphere at Kavalur is higher than that at Naini Tal.

3.2. *Atmospheric extinction in J, H, K bands*

We have determined the extinction in the J, H, K bands for Kavalur for 8 nights from our observations spread over a period of 3 years. We present these results in table 1. In

Table 1. Observation scheme and extinction coefficients in the J, H and K bands

Sl No.	Date of observation	HR number of the observed star	Spectral class	V mag	J mag	H mag	K mag	k_J extinction coefficient in J band	k_H extinction coefficient in H band	k_K extinction coefficient in K band	Mean absolute humidity during the night (gms/m^3)	Mean extinction coefficient k_J	k_H	k_K
1	23rd Jan 1988	5487	F2 III	3.87	3.12	2.94	2.89	0.17 (± .02)	0.14 (± 0.04)	0 18 (± .02)	12.1			
2	24rd Jan 1988	2693	F8 Ia	1.83	0.77	0.51	0.41	0.23 (± .02)	0.18 (± 0.02)	0.25 (± .03)	15.7			
3	1st Feb 1988	3314	A0V	3.90	3.94	3.92	3.93	0.12 (± .04)	0.07 (± .03)	0.08 (± .02)	14.5			
4	2nd Feb 1989	2970	K0 III	3.93	2.28	1.77	1.62	0.17 (± .01)	0.11 (± 0.01)	0.13 (± .01)	8.2			
5	20th Nov 1989	2580	K2 Iab	3.92	1.28	0.63	0.43	0.23 (± .02)	0.19 (± 0.03)	0 25 (± .02)	16.8	0.196	0.135	0.195
6	17th Dec 1989	4023	A2V	3.85	3.79	3.78	3.75	0.15 (± .01)	0.12 (± 0.04)	0.18 (± .02)	11.3			
7	5th Mar 1990	4695	K0 III	4.96	2.95	2.32	2.19	0.25 (± .03)	0.13 (± 0.01)	0.25 (± .02)	16.7			
8	6th Mar 1990	4662	B8 III	2.59	2.79	2.83	2.82	0.25 (± .05)	0.14 (± 0.05)	0.24 (± .05)	16.7			

figure 5 we present the wavelength dependence of the mean extinction coefficients. We show in the same figure the extinction coefficients obtained for UBVRI bands by Scaria & Bappu (1981) for Kavalur. In addition we have plotted in figure 5 the U, B, V and J, H, K extinction coefficients observed at Leh (Singh *et al.* 1989; Bhattacharyya *et al.* 1990) and the extinction coefficients in J, H, K bands for Siding Spring Observatory, Australia (Thomas *et al.* 1973) for comparison. Atmosphere, not only diminishes but also reddens the light passing through it. Longer wavelengths are attenuated less than the shorter ones. This wavelength dependence of the extinction coefficients for Mt Wilson and McDonald Observatories presented by Hardie (1962; his figure 3) is reproduced in figure 5. It is obvious that sky transparency at Kavalur is not as good as that at Leh or as that existed at Mt Wilson. Both are high altitude sites.

The spectral region covered by J, H, K filters are filled with many atmospheric molecular bands which although weak in intensity, attenuate appreciably the infrared radiation passing through the atmosphere over long slant paths. In figure 5, the extinction coefficient shows a smooth decrease with wavelength from U band to the I band. The sudden increase beyond the I band in the J, H, K bands is due to the many weak molecular absorption bands. Mean J, H, K extinction values for Kavalur are comparable with those for Siding Spring although the latter site is at a higher altitude (1140 m) than Kavalur.

Table 1 shows that extinction coefficients in J, H, K bands depend on absolute humidity prevailing during the night. In the month of February humidity and temperature are low and hence the extinction observed in the J, H, K bands are also low during this month. Even when the J, H, K extinction values are high (1990 March 5 and 6) sky is quite stable and gives a smooth extinction versus air mass plot. The night to night variations in the J, H, K extinction are large and so for accurate J, H, K

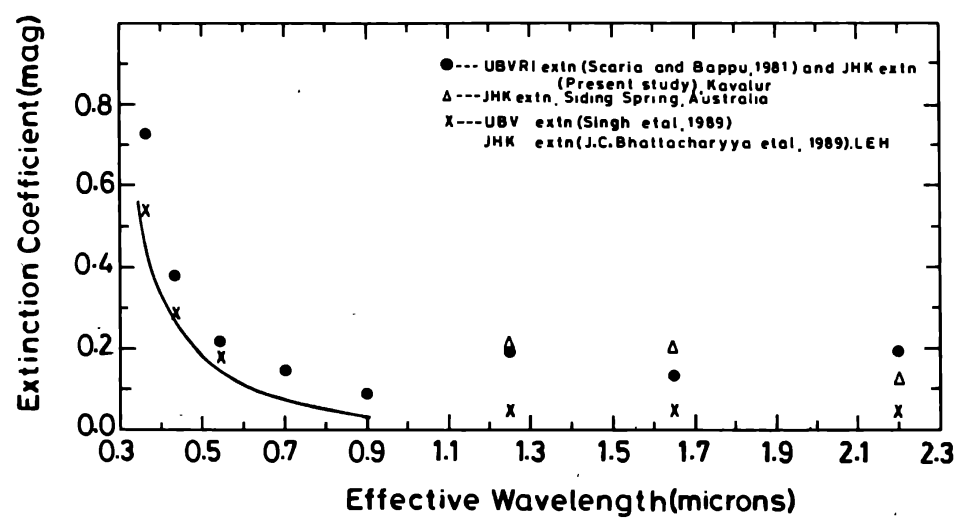

Figure 5. Extinction coefficients versus effective wavelengths. Filled circles UBVRI and JHK extinction coefficients for Kavalur. Open triangles (Δ) JHK extinction coefficients observed at Siding Spring, Australia, Thomas *et al.* (1973). Crosses (X) UBV and JHK extinction coefficients determined at Leh, India, Bhattacharyya (1990). The solid line represents the relation between extinction coefficients and effective wavelengths for the visual region at the Mount Wilson and McDonald Observatories and is reproduced from figure 3 of Hardie (1962).

photometry at Kavalur extinction coefficients must be determined if possible every night. The mean extinction coefficients given in table 1 can however be used for J, H, K photometry provided the observations are made close to the zenith.

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