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Extinction measurements at Leh

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Abstract. Observations were started at Leh in 1984 with a view to finding the possibility of setting up an astronomical observatory for infrared observations. Results of extinction measurements in UBV bands obtained on 12 nights during 1985–86 are presented. The average values of extinction coefficients are : $k_v = 0.20 \pm 0.13$ (s.d.), $k_b = 0.29 \pm 0.04$ and $k_u = 0.53 \pm 0.03$.

Key words : Photoelectric photometry—extinction coefficients—site survey

1. Introduction

Except for the recently selected site for an infrared observatory at Gurushikhar, Mount Abu, Rajasthan, no regular site for infrared observations exists in India. The essential requirement for such a site is in addition to availability of a large number of clear night with good steady seeing, very low moisture content in the air. As most of the water vapour is concentrated in the lower layers of the atmosphere, a high altitude location becomes imperative.

On preliminary grounds, the choice fell on area around Leh to study the possibility of setting up a high altitude observatory for infrared observations. Leh (latitude = 34° 09′ N, longitude = 77° 34′ E, altitude = 3500 m) is situated about 10 km north east of Indus river in the high plateau of Ladakh in the Himalayas and is surrounded by a ring of mountains of altitudes more than 4000 m. It is accessible by both air and road. The average annual rainfall (1931–1960) at Leh is 115 mm (IMD 1961). Also the sky is comparatively clear during the period June-September when most of India has almost continuous cloud cover due to summer monsoon. The very low water vapour content and an expected number of clear nights call for detailed observations to be made to determine the suitability of site for astronomical purpose.

The principal factors which decide the suitability of an astronomical site are the 'seeing' and the sky transparency. Transparency plays a major role in determining the photometric quality of the site; good and steady transparent skies are most essential while measuring the absolute brightness of astronomical objects. Star light, when it traverses through the earth's atmosphere, suffers a loss which can be expressed as

$$m_0 = m - kX, \tag{1}$$

where m_0 is the magnitude of a star as it appears outside the earth's atmosphere, m the actual observed magnitude through a path length X in the atmosphere and k the extinction coefficient. Normally, X is measured in units of the airmass at the zenith of the observer and hence k is the loss in magnitude for a star at the zenith, obtained as the slope of $m_0 - X$ line.

2. Instrument and observations

A 50-cm reflecting telescope (the 'Bhavnagar' telescope) was installed in Skara village 3 km from Leh town in 1984 October*. Although a smaller telescope would have sufficed for monitoring the sky transparency, this large aperture telescope, readily available, was chosen because some of the observational programs could also be carried out along with the site evaluation work (Ashoka & Pukalenthi 1986; Paranjpye & Babu 1986). A conventional photoelectric photometer attached to the telescope was used for the observations. We used the following Schott filters (Henden & Kaitchuk 1982)

U UG 2 (2 mm)

B GG 13 (2 mm) + BG 12 (2 mm)

V GG 14 (2 mm)

having bandwidths around 1000Å and centred respectively around wavelengths 0.36μ, 0.43μ, and 0.55μ. An uncooled RCA 1P21 photomultiplier tube was used as the detector. The output from the photomultiplier was registered on a d.c. chart recorder after amplification by a solid state electrometer amplifier. The amplifier, built in our laboratory following Oliver (1975), has gain control switches in the half-magnitude steps and thus is very convenient at the telescope. Each set of observations consisted of two measurements on the object in either UBVVBU or VBUUBV order. The mean time of the observations was taken for the calculation of the airmass and the mean of the two measurements in each filter for magnitude computations. Through each filter the output was traced for half to one minute duration.

*Actinometric observations at Leh for about two years starting from the summer of 1883 were made under the aegis of Survey of India by Sgt Rowland and his assistant Mr Shaw on the suggestion of the Solar Physics Committee, South Kensington. The observations made with a Balfour Stewart actinometer showed the presence of a large amount of dust. Later suggestion by the Solar Physics Committee to repeat the survey with a better, chemical actinometer made by Professor Roscoe could not be carried out because of logistical reasons (Kochhar 1988).

3. Results and discussion

During the period 1985 March–1986 November we attempted to quantitatively determine the sky transparency on several nights. Observations covering large range of airmasses could be obtained only on 12 different nights. The plots of the v, $(b - v)$ and $(u - b)$ magnitudes against the corresponding airmasses are given in figures 1 and 2. The slope of each line was determined using least square fit to the data and the values thus calculated are given in table 1. The table lists dates of observations, star identification and spectral type and extinction

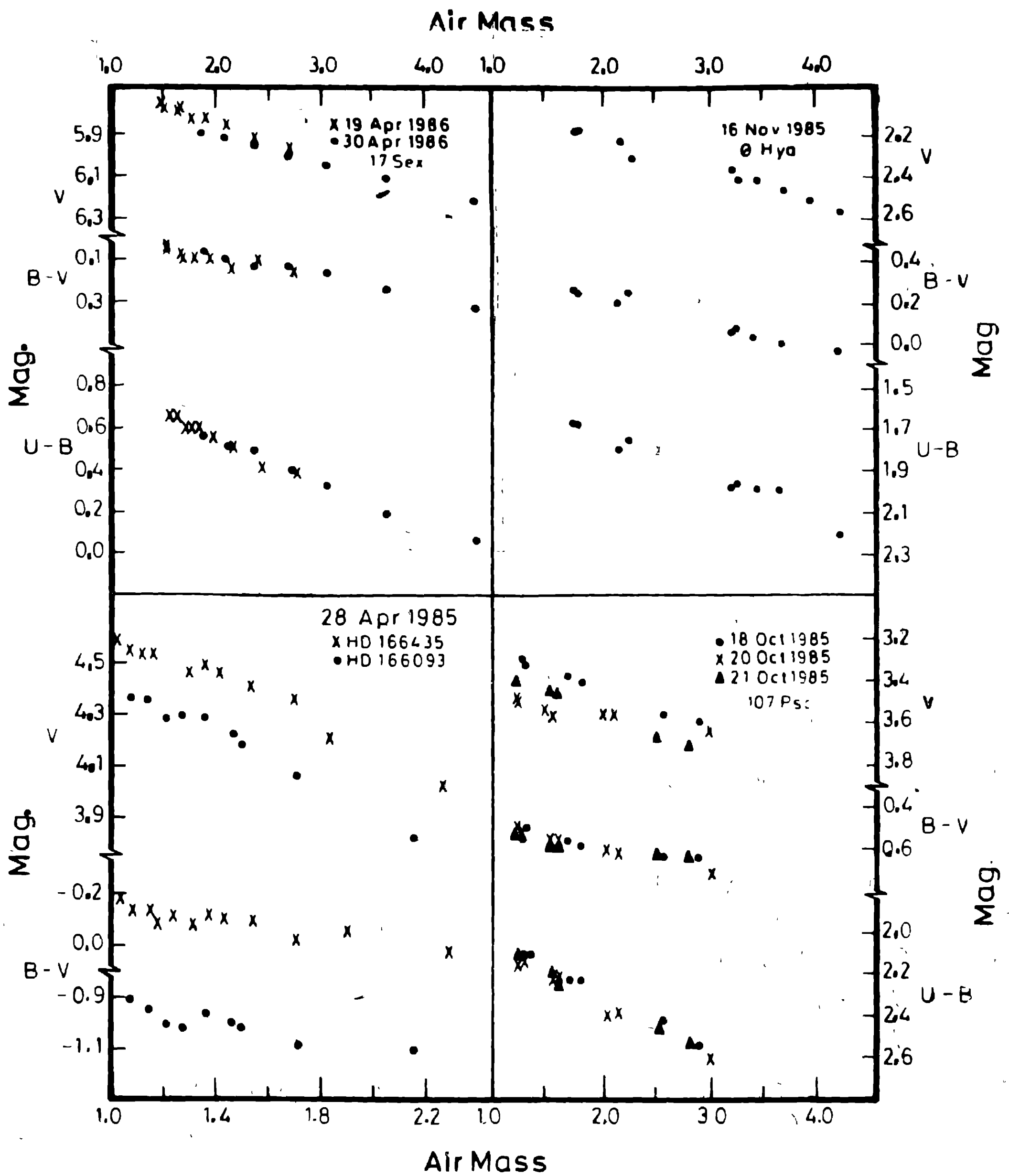

Figure 1. Plot of magnitude versus airmass. Dates of observation and identification of star are indicated.

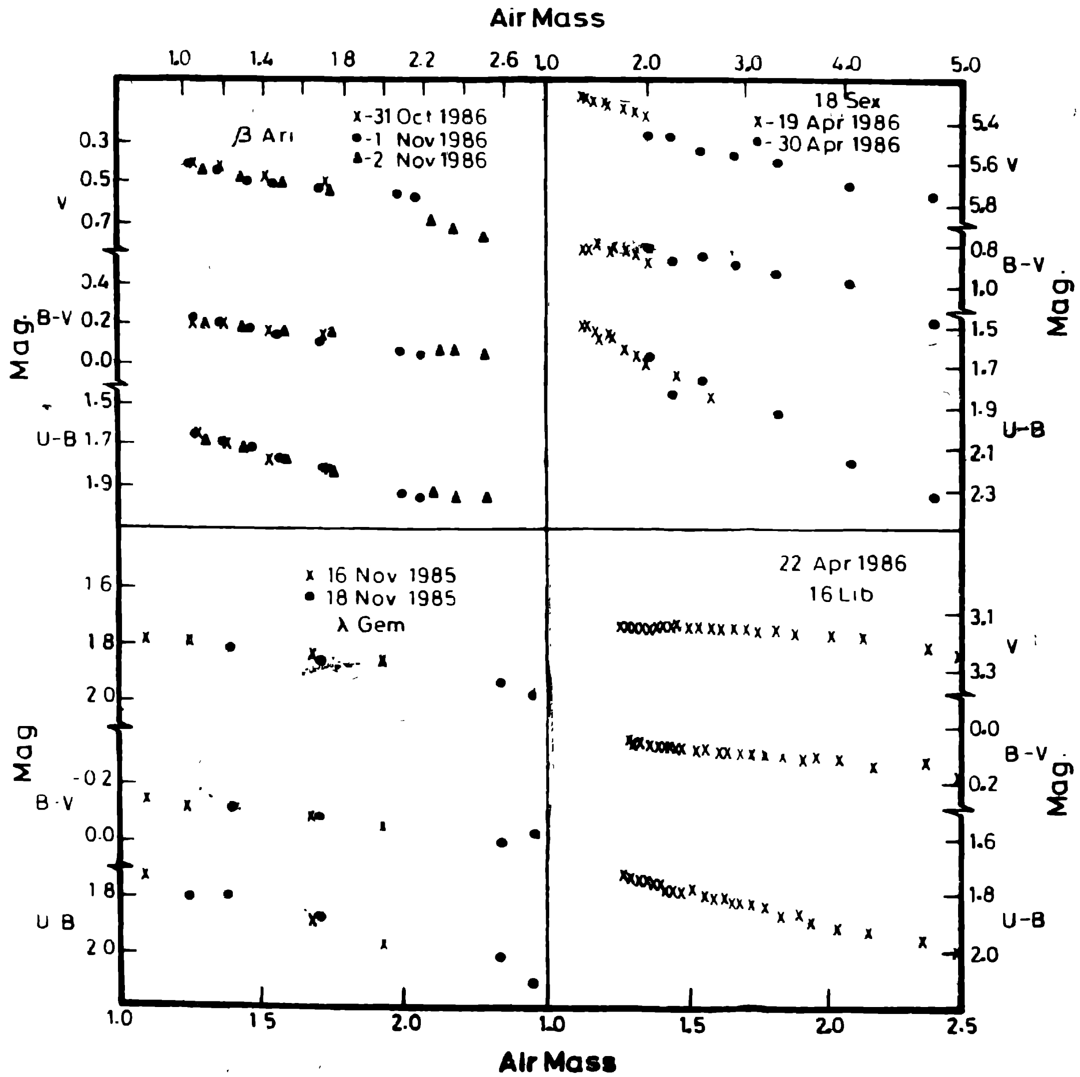

Figure 2. Same as that of figure 1.

coefficients in v, $b - v$, and $u - b$. The last row in table 1 gives the average values and the standard deviations of k in v, $(b - v)$, and $(u - b)$ which are usually denoted by k_v, k_{bv}, and k_{ub}. Here one may note that the extinction coefficients may vary with both time and direction due to possible variations in the atmospheric constituents. From the definitions of the magnitude and the extinction coefficients, it is clear that

$$k_b = k_{bv} + k_v$$
$$k_u = k_{ub} + k_b.$$

The extinction coefficients k_v, k_b, and k_u have been found to vary between 0.1–0.4, 0.2–0.5 and 0.4–0.6 respectively and the average values are $k_v = 0.20 \pm 0.13$, $k_b = 0.29 \pm 0.04$ and $k_u = 0.53 \pm 0.03$.

It is interesting to compare these values with those obtained at Vainu Bappu Observatory, Kavalur, by two of us (A. V. Raveendran & S. Mohin). In figure 3

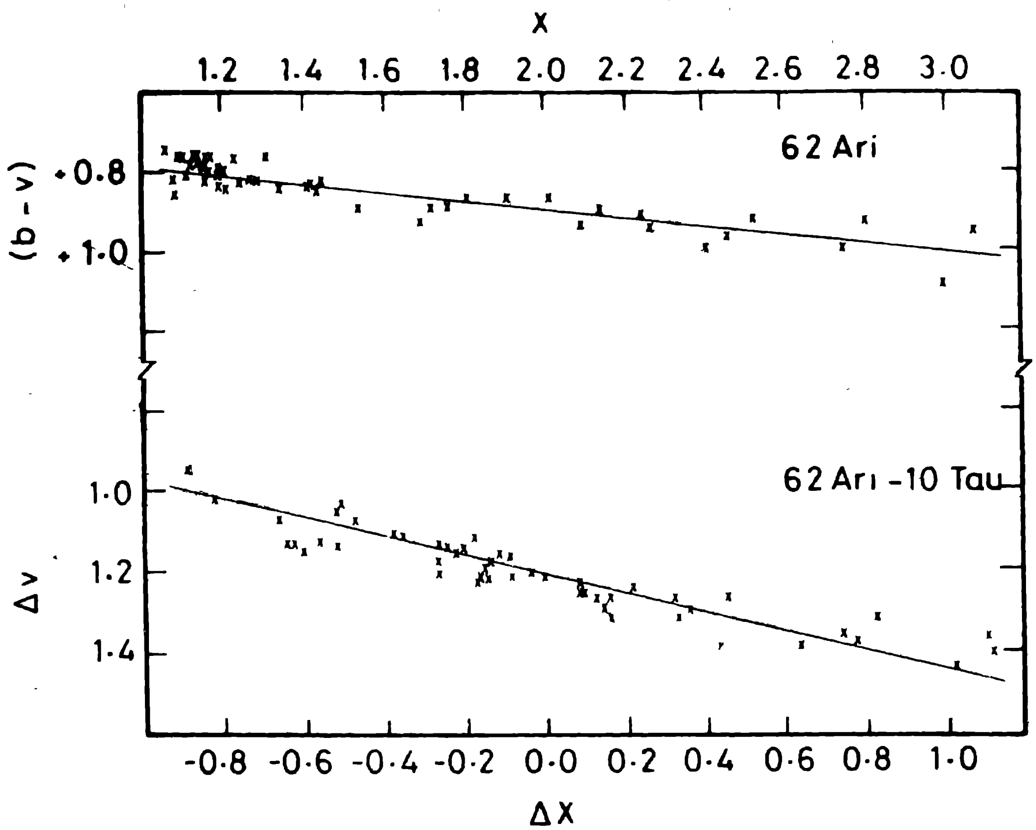

Figure 3. Top : Plot of ($b - v$) of 52 Ari against the airmass. Bottom : Plot of the differential v magnitude (62 Ari–10 Tau) against the respective differential airmass.

(bottom) are plotted the differential v magnitudes of two standard stars 62 Ari ($V = 5.52$, G5 III) and 10 Tau ($V = 4.28$, F9V) against the corresponding differential airmass obtained at Kavalur on 25 nights during 1987 January–March. This procedure was adopted essentially to remove the uncertainties in the zero point of magnitude when data collected over several nights are combined. Top portion

Table 1. Extinction coefficients

Date		v	$b - v$	$u - b$	Star (Sp. type)
1985	Apr 28	0.41±0.02	0.16±0.01		HD 166093 (K2)
	Apr 28	0.49±0.02	0.13±0.01		HD 166435 (G5 V)
	Oct 18	0.16±0.01	0.07±0.01	0.25±0.01	107 Psc (K1 V)
	Oct 20	0.06±0.01	0.11±0.01	0.26±0.01	107 Psc (K1 V)
	Oct 21	0.60±0.01	0.07±0.01	0.26±0.01	107 Psc (K1 V)
	Nov 16	0.29±0.05	0.12±0.01	0.28±0 03	θ Hya (B9.5 V)
	Nov 16 & 18	0.20±0.03	0.08±0.02	0.16±0.04	λ Gem (A3 V)
1986	Apr 19	0.15±0.01	0.05±0.01	0.26±0.02	17 Sex (A1 V)
	Apr 19	0.21±0.02	0.02±0.02	0.22±0.01	18 Sex (K2 III)
	Apr 22	0.06±0.01	0.08±0.01	0.23±0.01	16 Lib (F0 V)
	Apr 30	0.11±0.01	0.11±0.01	0.23±0.02	18 Sex (K2 III)
	Apr 30	0.12±0.01	0.10±0.01	0.24±0.01	17 Sex (A1 V)
	Oct 31 & Nov 1 & 2	0.18±0.01 0.20±0.13	0.12±0.01	0.23±0.01	β Ari (A5 V)
	Average	0.20±0.13	0.09±0.04	0.24±0.03	

of figure 3 contains the plot of $(b - v)$ colours of 62 Ari, again obtained on 25 nights during the same period, against the respective airmass. Least square solutions give $k_V = 0.234 \pm 0.008$ and $k_b = 0.341 \pm 0.008$, representing the averages for the above period. No measurements were made in U filter during this period. However, observations made during the 1979–80 observing season gave an average value for k_u as 0.75 ± 0.04 (A. V. Raveendran & S. Mohin, unpublished).

Since the data sample is very limited, no meaningful deductions can be made about the seasonal variation of extinction coefficients at Leh. Efforts are in progress to determine the extinction coefficients on a large number of nights so that we could obtain a better picture about the sky transparency at Leh and thereby make a detailed comparison with other observatory sites in the world. From our visual observations there is an indication that the skies have better transparency during October–November period than during April–June.

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