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Some further characteristics of observing conditions at Leh

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Abstract. The sky conditions were monitored and duration of photometric and spectroscopic hours determined on 198 nights during the period 1984 September to 1986 October. Observations were continued from 1987 May till November and again from 1988 June to October, when additionally the temperature and relative humidity values were systematically recorded. Several standard stars were monitored on several nights to determine the extinction coefficients in UBV bands; in addition sky brightness was measured on eight nights in the months of 1988 September and October. The values of sky brightness appear to be marginally higher than at La Palma. The average values of extinction coefficients, determined on 27 nights during 1988 show a general agreement with the earlier values.

Key words : astronomical seeing—relative humidity—photometric and spectroscopic sky—extinction coefficients—sky brightness—site survey

1. Introduction

The results of extinction measurements done on 12 nights during the period 1985-86 were reported earlier by Singh *et al.* (1988). The temperature, relative humidity, sky conditions, image quality, and extinction measured at Leh during the period 1987 May-November were presented in a later paper (Singh *et al.* 1989). We have monitored all these five quantities at Leh during the period 1988 June-October also in a more intensive way. In addition the sky brightness in *UBV* bands on eight nights in the months of September and October has been measured. Observations at Leh were stopped in 1988 November. In this paper we report the measurements of the sky brightness in *UBV* bands and the last batch of results of all other observations.

2. Results

2.1. *Sky brightness*

The night time sky brightness at Leh has been measured with the help of photometric photometer attached to the 51 cm Bhavnagar telescope. This has been determined at an

altitude of about 50-60° and for the period without moon and twilight. The star γ Lyrae was chosen for comparison. The deflections through *UBV* filters were recorded with the above star and immediately afterwards deflection of the nearby sky without any star in the field was obtained with a calibrated high magnification of d.c. amplifier. The values of sky brightness were computed from these observations for eight nights using the expression

$$m \text{ (sky)} = m_2 - m_1 + m \text{ (star)}$$

where m_2 and m_1 are the observed magnitudes of the sky and star respectively through an aperture of 6 mm while m (star) is the apparent magnitude of the star. Then the values of sky brightness in magnitude per square arcsec were determined by using the values of m (sky), image scale and aperture size. These values are listed in table 1 along with the average values in *UBV* filters. The values of sky brightness in *UBV* bands at La Palma (latitude 28.7 N, altitude 2400 m) are also given in table 1 (Murdin 1985). Walker (1986) says that at a very dark site under favourable circumstances the sky brightness at zenith in *V* and *B* bands should be approximately 22.0 and 23.0 magnitudes per square arcsec respectively. At an altitude of about 5 degree the sky will be approximately 0.5 magnitude brighter as compared to zenith.

Table 1. Sky brightness at Leh

Date	Meantime of observations IST	Sky brightness in mag. per arcsec^2 *V*	*B*	*U*
1988 Sep. 4	22.19	20.94	21.62	20.92
Sep. 5	21.58	20.90	21.46	20.94
Sep. 7	22.49	20.79	21.35	20.67
Sep. 12	23.00	20.97	21.57	20.84
Sep. 13	22.07	20.49	21.20	20.58
	22.58	20.76	21.36	20.83
Sep. 14	22.13	20.47	20.93	20.51
Oct. 5	21.32	20.94	21.59	20.80
Oct. 6	21.52	20.50	21.13	20.42
Average at Leh		20.75 ± .20(s.d.)	21.41 ± .22(s.d.)	20.72 ± .18(s.d.)
At La Palma		21.40	22.30	21.40

2.2. *Clear nights*

The definition of a clear night, a photometric hour and a spectroscopic hour is the same as given by Singh *et al.* (1989). The sky conditions could be monitored only for short intervals during the period 1984 September-1986 October. Thus we have the data for 198 nights only out of the possible 757 nights during this entire period. The epoch of these observations and the number of nights, along with the corresponding photometric and spectroscopic hours and number of clear nights are listed in table 2 for this period. It may be noted that observations were made in the months of January, February and March only in 1985 and these months were not covered during later years. The monitoring of sky conditions was done only on about 26% of the nights but the average percentage of

Table 2. Number of photometric and spectroscopic hours

Epoch of observations		No. of days	Photo-metric hours	Spectro-scopy hours	Full clear nights
1984	Sep. 26-Nov. 19	46	126	179	15
1985	Jan. 18-Mar. 7	41	166	194	17
	Apr. 18-May 8	21	36	70	5
	Nov. 8-Nov. 20	13	79	94	8
1986	Jun. 11-Jun. 30	20	59	83	8
	Jul. 1-Jul. 31	17	24	37	2
	Aug. 1-Aug. 12	12	15	37	1
	Sep. 25-Oct. 22	28	82	108	10
	Total	198	587	802	66

clear nights during this period comes out to be similar to the period of 1987 May-November.

The number of photometric and spectroscopic hours and clear nights at Leh during the period of 1988 June-October are listed in table 3. For comparison the corresponding figures for the Vainu Bappu Observatory, Kavalur are also given. Table 3 indicates that only 24 (16%) nights were clear in this period as compared to 32 (21%) nights in the corresponding months of 1987. It also indicates that number of clear nights is always more at Leh as compared to Kavalur during these five months, a result similar to 1987 period. In figure 1 we have plotted the frequency of number of nights as a function of photometric and spectroscopic hours for the period 1988 June-October. The figure shows that on 34% of nights spectroscopic work could have been done as compared to 40% during 1987.

Table 3. Number of photometric and spectroscopic hours per month at Leh and Kavalur

Month		Photometric hours		Spectroscopic hours		No. of clear nights	
		Leh	Kavalur	Leh	Kavalur	Leh	Kavalur
1988	Jun.	68	3	98	87	5	0
	Jul.	51	2	77	25	4	0
	Aug.	37	0	84	20	1	0
	Sep	52	12	105	56	6	0
	Oct.	82	27	142	114	8	1

2.3. *Temperature*

We have monitored the temperature near the telescope four times every night during the period 1988 June-October. The temperature values as a function of the night and time are shown in figure 2 which indicates that the temperature continues to rise and reaches a maximum ($\sim$ 23C) by the end of June. The day to day variation is large in the early part of the night as compared to the later part during July-August. The temperature starts declining by the middle of August and continues this trend till the close of our observations in the month of November. As done earlier the difference of dusk and dawn values is plotted in figure 3 for each respective night. This figure shows that this variation

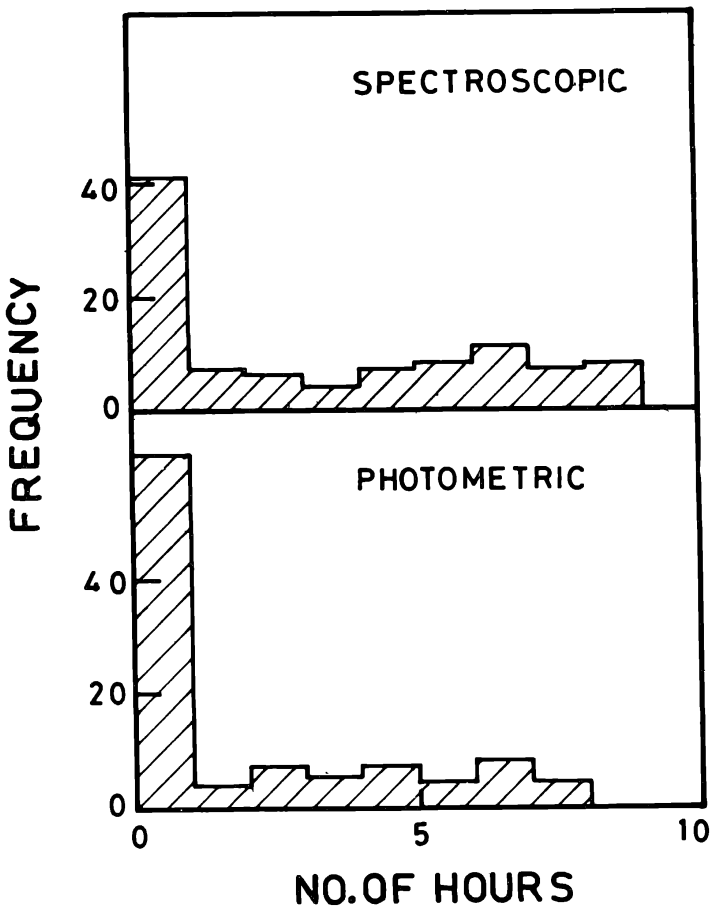

Figure 1. Frequency distribution of number of nights of photometric and spectroscopic hours vs. number of hours per night for the period 1988 June-October.

in temperature during the night is generally between 3 to 10C with an average value of 7C which is same as that in the year 1987.

2.4. *Humidity*

The percentage relative humidity was recorded four times each night using a calibrated hair hygrometer, in continuation of earlier observations (Singh *et al.* 1989). A plot of these values for each night at four times is shown in figure 4. On comparing the 1988 values with the corresponding values of 1987 one finds that percentage relative humidity is generally the same in the months of June, August, and October while July and September values show an increase in humidity. The difference between the last and the first value of each night has been plotted against their respective dates in figure 5. The differences show a close similarity in variations except for the month of June. In this month the change in percentage relative humidity during night was about 20% in 1988 indicating more moist conditions as against less than 10% in 1987.

2.5. *Seeing conditions*

Astronomical seeing observations were continued for the period 1988 June-October. The number of hours with seeing <1, 1-2, 2-3 and >3 arcsec for each month are listed in

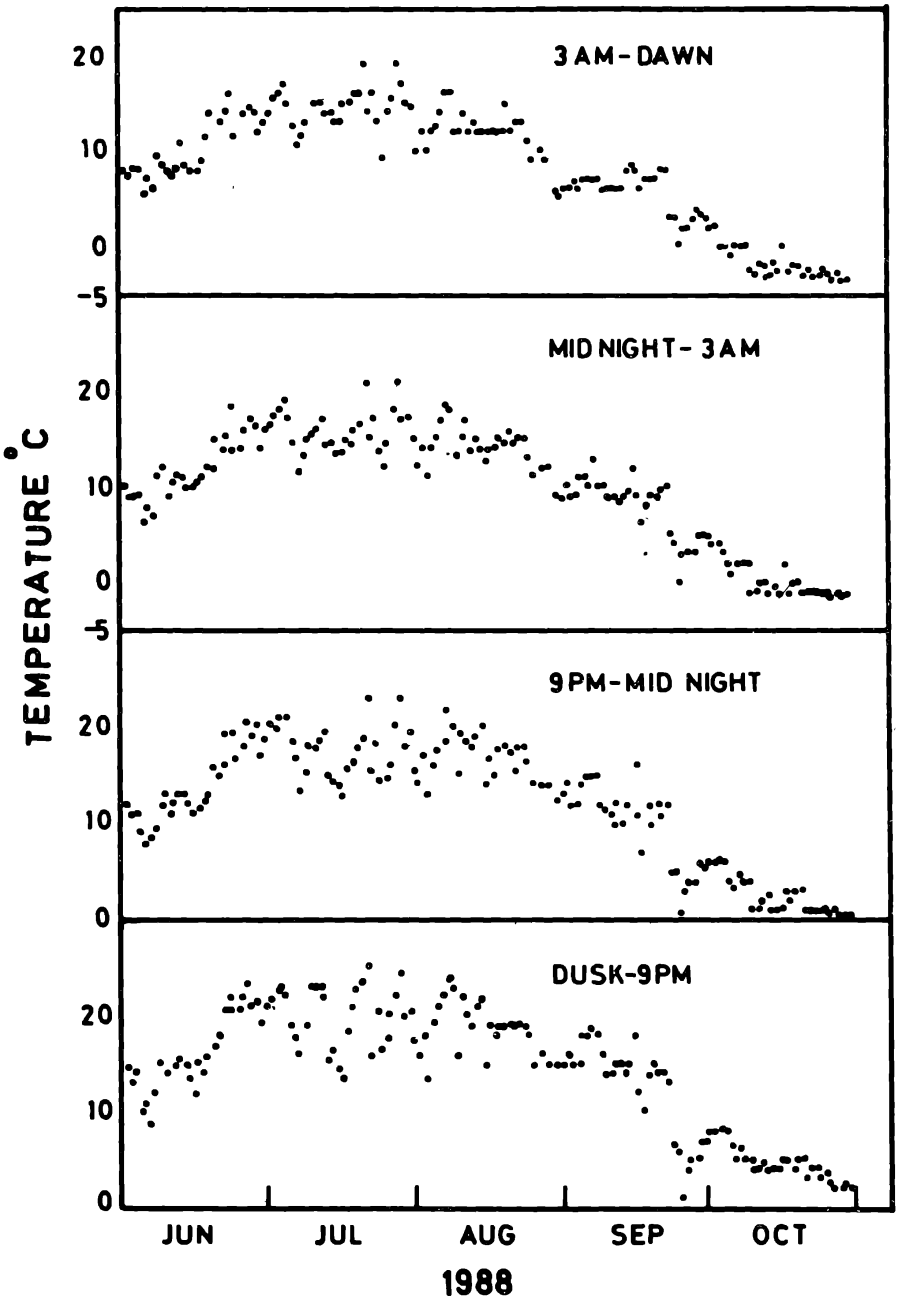

Figure 2. Values of temperature in the course of each night taken at an interval of 3 hours during the period 1988 June-October.

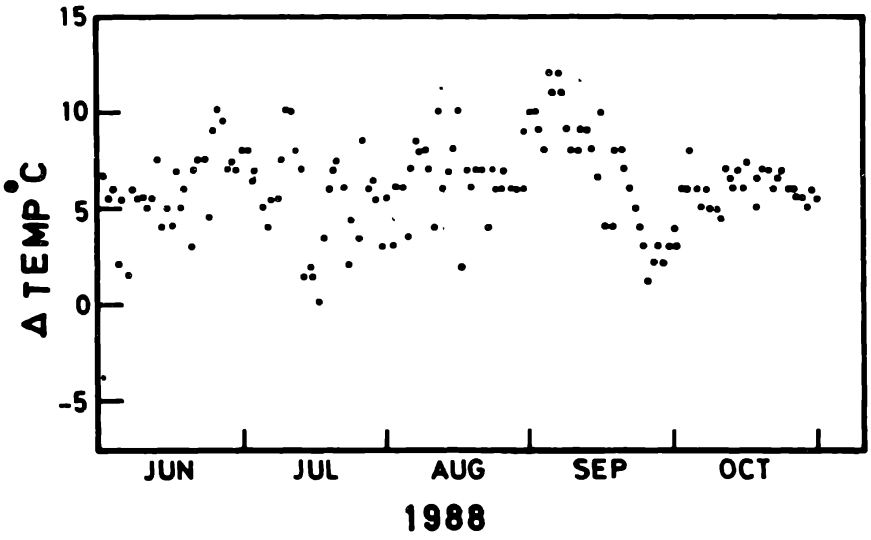

Figure 3. Variation of temperature between dusk to dawn during the period 1988 June-October.

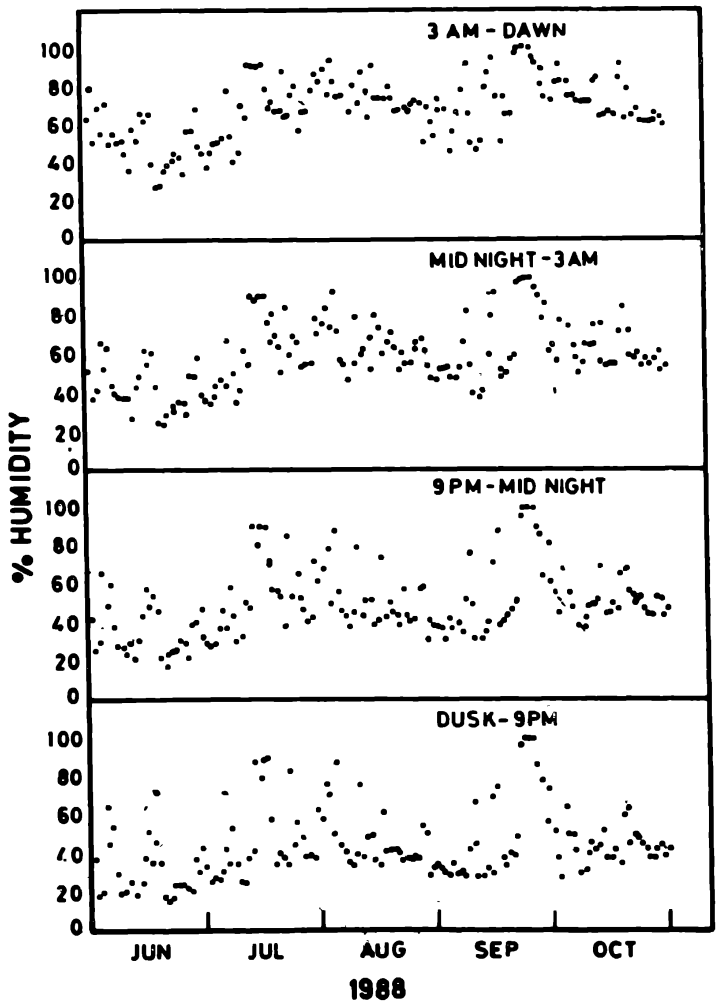

Figure 4. Values of percentage relative humidity during the nights taken at an interval of 3 hours during the period of 1988 June-October.

table 4. The values indicate that number of hours with good seeing (1-2 arcsec) are more in the months of June, July, and October as compared to August and September. This feature is similar to the trend observed earlier.

2.6. *Transparency of the sky*

Several standard stars were observed on 27 nights during this period to determine the extinction coefficients in *UBV* bands. The values of extinction coefficients $k(v)$, $k(b-v)$, and $k(u-b)$ are given in table 5 along with the date, star name, spectral type, and

Table 4. Seeing conditions in number of hours per month

Month		No. of hours with seeing (in arcsec)			
		<1	1-2	2-3	>3
1988	Jun.	0	96	2	0
	Jul.	0	59	13	5
	Aug.	4	25	42	13
	Sep.	0	53	30	22
	Oct.	0	89	28	25

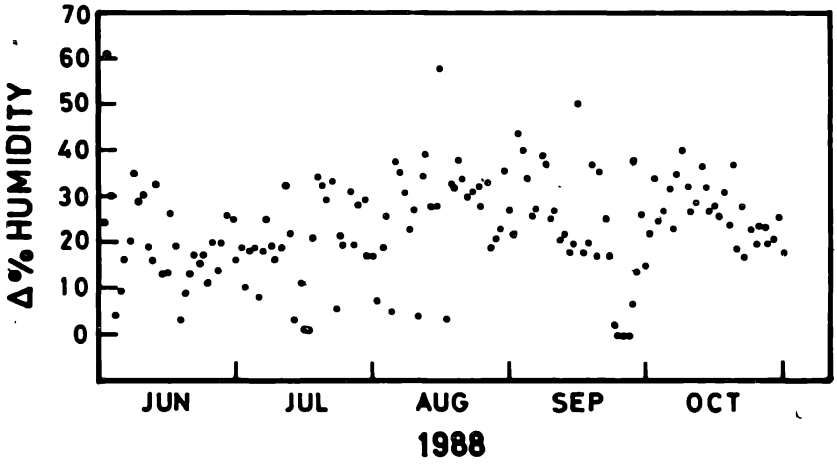

Figure 5. Variation of percentage relative humidity between dusk to dawn during the period 1988 June-October.

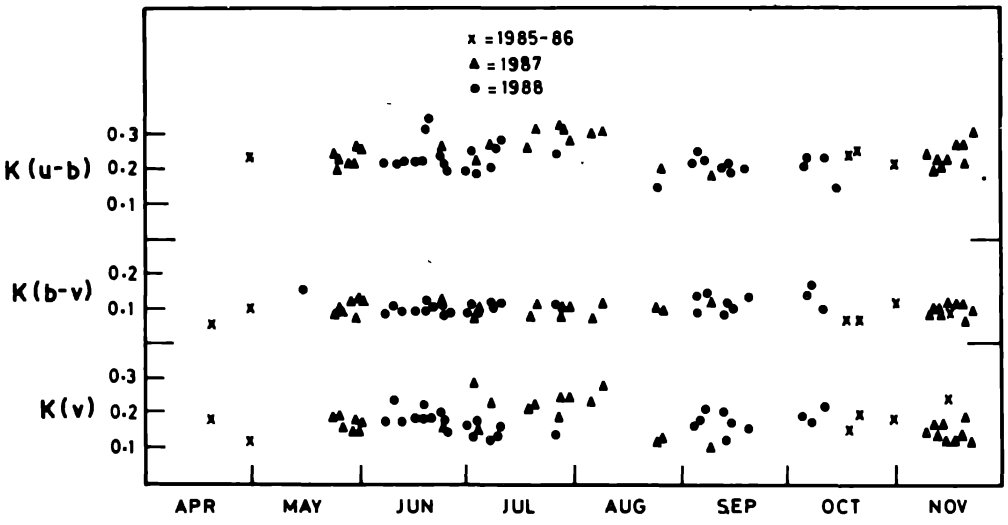

Figure 6. Extinction coefficients during the period 1985-88. X, • and ▲ represent the values of k in 1985-86, 1987 and 1988 respectively.

Table 5. Extinction coefficients

Date	Star name	Sp type	Mag V	$K(V)$	$K(b-v)$	$K(u-b)$
1988 Jun. 07	β Com	GOV	4.26	0.17 ± 0.029	0.09 ± 0.040	0.22 ± 0.040
Jun. 10	12 Com	GOIII+A3V	4.81	0.25 ± 0.005	0.10 ± 0.007	0.21 ± 0.009
Jun. 10	17 Com	AOP	5.29	0.23 ± 0.004	0.12 ± 0.010	0.23 ± 0.010
Jun. 12	12 Com	GOIII+A3V	4.81	0.17 ± 0.006	0.08 ± 0.007	0.22 ± 0.009
Jun. 12	17 Com	AOP	5.29	0.17 ± 0.009	0.09 ± 0.010	0.23 ± 0.010
Jun. 16	τ Boo	F6IV	4.50	0 18 ± 0.005	0.09 ± 0.008	0.22 ± 0.010
Jun. 18	θ CrB	BOV	4.14	0.20 ± 0.006	0.09 ± 0.011	0.22 ± 0.017
Jun. 18	γ CrB	B9IV+A3V	3.84	0.18 ± 0.005	0.10 ± 0.008	0.20 ± 0.009
Jun. 19	β Com	GOV	4.26	0.22 ± 0.035	0.12 ± 0.013	0.31 ± 0.015
Jun. 20	β Com	GOV	4.26	0.18 ± 0.010	0.10 ± 0.010	0.34 ± 0.027
Jun. 20	τ Boo	F6IV	4.50	0.20 ± 0.004	—	—
Jun. 23	109 Vir	AOV	3.72	0.19 ± 0.002	0.10 ± 0.004	0.24 ± 0.005
Jun. 24	τ Boo	F6IV	4.50	0.17 ± 0.004	0.08 ± 0.004	0.21 ± 0.008
Jun. 25	109 Vir	AOV	3.72	0.14 ± 0.002	0.08 ± 0.004	0.19 ± 0.005
Jul. 01	58 Agl	AOIII	5.61	0.16 ± 0.006	0.08 ± 0.007	0.19 ± 0.012
Jul. 02	58 Agl	AOIII	5.61	0.13 ± 0.005	0.10 ± 0.007	0.25 ± 0.009
Jul. 03	58 Agl	AOIII	5.61	0.17 ± 0.008	0.09 ± 0.008	0.18 ± 0.008
Jul. 08	109 Vir	AOV	3.72	0.12 ± 0.005	0.11 ± 0.007	0.20 ± 0.013
Jul. 09	109 Vir	AOV	3.72	0.14 ± 0.003	0.10 ± 0.004	0.26 ± 0.006
Jul. 10	θ CrB	B6V	4.14	0.16 ± 0.046	0.11 ± 0.046	0.28 ± 0.030
Jul. 26	θ CrB	B6V	4.14	0.14 ± 0.004	0.11 ± 0.009	0.24 ± 0.009
Jul. 26	γ CrB	B9IV+A3V	3.84	0.14 ± 0.007	0.11 ± 0.023	0.24 ± 0.023
Sep. 04	γ Lyr	B9III	3.25	0.16 ± 0.009	0.13 ± 0.009	0.21 ± 0.010
Sep. 05	γ Lyr	B9III	3.25	0.17 ± 0.004	0.08 ± 0.005	0.25 ± 0.009
Sep. 07	γ Lyr	B9III	3.25	0.21 ± 0.006	0.13 ± 0.020	0.22 ± 0.020
Sep. 12	γ Lyr	B9III	3.25	0.19 ± 0.006	0.08 ± 0.006	0.21 ± 0.009
Sep. 13	γ Lyr	B9III	3.25	0.12 ± 0.002	0.11 ± 0.003	0.21 ± 0.008
Sep. 14	γ Lyr	B9III	3.25	0.17 ± 0.004	0.10 ± 0.007	0.19 ± 0.013
Sep. 19	γ Lyr	B9III	3.25	0.15 ± 0.004	0.13 ± 0.010	0.20 ± 0.012
Oct. 05	γ Lyr	B9III	3.25	0.18 ± 0.007	0.13 ± 0.008	0.21 ± 0.010
Oct. 06	γ Lyr	B9III	3.25	0.17 ± 0.018	0.16 ± 0.028	0.23 ± 0.036
Oct. 11	γ Lyr	B9III	3.25	0.21 ± 0.007	0.09 ± 0.009	0.23 ± 0.015
	Average			0.17 ± 0.03 (s.d.)	0.10 ± 0.02 (s.d.)	0.23 ± 0.03 (s.d.)

magnitude of the star. The table shows that the values of extinction coefficients determined from these observation of two different stars on the same night agree well with each other and therefore represent consistent sky conditions. The average values of extinction coefficients during this period are $k(v) = 0.17 \pm 0.03$ (s.d.), $k(b) = 0.27 \pm 0.03$ (s.d.) and $k(u) = 0.50 \pm 0.03$ (s.d.) and agree well with those of 1985-86 and 1987. To see the seasonal variation in the sky transparency we have plotted all values of extinction coefficients in figure 6 as a function of day and month. This figure indicates that the values are higher in July and August as compared to other months and verifies the result of 1987 data.

3. Conclusions

The measurements indicate that the sky brightness at Leh is about 21 mag which is about 0.7 mag brighter than that at La Palma. This may be due to the presence of fine aerosols

in the sky over Leh. Number of clear nights were less during this period of 1988 as compared to those in the corresponding period of 1987. The temperature and its variations during 1988 were similar to those recorded in 1987. There was a small increase in relative humidity in July and September 1988 as compared to the corresponding months of 1987. This might be due to the fact that monsoon was more active in 1988 as compared to 1987 (*cf.* meteorological reports). Seeing conditions were similar to those observed in 1987. The extinction coefficients measured on 27 nights during this period agreed well with those of 1985-87.

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