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Atmospheric Extinction at the Roque de los Muchachos Observatory, La Palma

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Introduction

The wavelength dependence of the atmospheric extinction at the Roque de los Muchachos Observatory is currently in the process of being measured. Until these data become available, a satisfactory approach for many applications is to correct spectroscopic and photometric observations using a theoretical extinction curve, calculated as suggested by Hayes and Latham (1975). Comparisons between calculated and observed mean extinction coefficients for Lick and Cerro Tololo observatories appear to suggest that the calculated extinction curve is probably accurate to within a few hundredths of a magnitude. This is also borne out by available data for La Palma (see below).

This note gives such a theoretical extinction curve, appropriate to the altitude of the Roque de los Muchachos observatory and covering the spectral range 3000-11000 A**.** The data are presented in graphical and tabular form. Furthermore, this extinction curve is available to SPICA Users in the VAX file:
RGVAD::LDRUGDIR:LAPALMA.EXT

Calculated Extinction Curve

The three main contributions to extinction by the Earth's atmosphere of relevance to ground-based astronomy are Rayleigh scattering by air molecules, molecular absorption and aerosol scattering. The method outlined by Hayes and Latham (1975) gives the mean extinction for an aerosol-free atmosphere, as follows:

1) Rayleigh scattering
The wavelength (λ in μm) and altitude (h in km) dependence of Rayleigh vertical extinction (magnitudes per unit air mass) is approximated by:

$$A_{Ray}(\lambda,h) = 9.4977 \times 10^{-3} \times \lambda^{-4} \left((n-1)_{\lambda} / (n-1)_{\lambda=1}\right)^2 \times e^{-h/7.996} \qquad (1)$$

where the scale height of the lower troposphere is taken to be 7.996 km and h = 2.369 km for the Roque de los Muchachos Observatory.

The index-of-refraction term is given by:

$$(n-1)_{\lambda}/(n-1)_{\lambda=1} = 0.23465 + (1.076 \times 10^{2})/(146 - \lambda^{-2}) + 0.93161/(41 - \lambda^{-2}) \qquad (2)$$

2) Molecular Absorption
The major contributors are absorption bands of ozone and water vapour. The latter is not included in the calculated extinction curve, because the amount of water vapour above any observatory is extremely variable. Water vapour bands can contribute more than 0.01 mag extinction per unit air mass at 7100, 8090, 9700 and 10800 A.

Vertical extinction by ozone is approximated by:

$$A_{oz}(\lambda) = l.11\, T_{oz}\, K_{oz}(\lambda) \qquad (3)$$

where K_{oz} (cm^{-1}) is the absorption coefficient (Gast 1960), and T_{oz} (atm cm) is the total ozone above the observatory. T_{oz} is independent of the observatory altitude, since atmospheric O_3 is concentrated between 10 and 35 km. It does, however, exhibit seasonal variations and it can also vary significantly on time scales as short as a few hours. The extinction curve given here uses a mean annual value of T_{oz} appropriate to the latitude of La Palma, taken from Allen (1963).

The total vertical extinction coefficient $A(\lambda)$ for an aerosol-free atmosphere is then given by:

$$A(\lambda) = A_{Ray}(\lambda,h) + A_{oz}(\lambda) \tag{4}$$

Values of $A(\lambda)$ have been calculated every 10 A between 3000 and 3500 A and every 50 A between 3500 and 11000 A, and are collected in Table 1. The extinction curve is shown in Figure 1, together with preliminary measurements obtained on dust-free nights (Andrews 1985, private communication).

Correction for Dust Extinction

To correct observations for total extinction, the contribution from aerosol scattering must be included. Available data (Jones 1984) suggest that to a first approximation the dust scattering at the Roque de los Muchachos observatory does not depend strongly on wavelength over the range considered here. In this case the dust correction term to the extinction curve can be deduced by comparing A(V), the theoretical extinction coefficient in the V band calculated as in (4) above, with $A_{CAMC}(V)$ the observed mean extinction coefficient in V measured on the night of the observations by the Carlsberg Automatic Transit Circle group at the Roque de los Muchachos Observatory:

$$A_{Aer} = A_{CAMC}(V) - A(V) \tag{5}$$

Values of $A_{CAMC}(V)$ for nights of interest can be obtained upon request from the Meridian Group at RGO Herstmonceux (in the first instance contact L V Morrison on ext. 3365). and will shortly be available on line from a file on the RGO Starlink VAX.

The total vertical extinction is then given by:

$$A_{TOT}(\lambda) = A(\lambda) + A_{Aer} \tag{6}$$

References

Allen, C.W., 1963 Astrophysical Quantities (London: Athlone Press) 2nd edition.

Gast, P.R., 1980 Handbook of Geophysics, USAF, Cambridge Research Centre (New . York: MacMillan)

Hayes, D.S. and Latham D.W., 1975 Ap. J. 197, 593

Jones, D.H.P., 1984 RGO/La Palma Technical Note 10

Table 1 Calculated Atmospheric Extinction at the Roque de los Muchachos Observatory

Wavelength (angstroms)	Extinction (mag/airmass)	Wavelength (angstroms)	Extinction (mag/airmass)	Wavelength (angstroms)	Extinction (mag/airmass)	Wavelength (angstroms)	Extinction (mag/airmass)
3000	3.7150	3750	0.3839	6500	0.0575	9250	0.0097
3010	3.3105	3800	0.3633	6550	0.0547	9300	0.0095
3020	2.9638	3850	0.3440	6600	0.0524	9350	0.0093
3030	2.6782	3900	0.3260	6650	0.0500	9400	0.0091
3040	2.4211	3950	0.3092	6700	0.0473	9450	0.0089
3050	2.2140	4000	0.2935	6750	0.0450	9500	0.0087
3060	2.0423	4050	0.2787	6800	0.0428	9550	0.0085
3070	1.9001	4100	0.2649	6850	0.0407	9600	0.0083
3080	1.7822	4150	0.2519	6900	0.0389	9650	0.0082
3090	1.6826	4200	0.2397	6950	0.0371	9700	0.0080
3100	1.5961	4250	0.2283	7000	0.0356	9750	0.0078
3110	1.5169	4300	0.2175	7050	0.0342	9800	0.0077
3120	1.4393	4350	0.2079	7100	0.0330	9850	0.0075
3130	1.3579	4400	0.1986	7150	0.0319	9900	0.0074
3140	1.2670	4450	0.1896	7200	0.0307	9950	0.0072
3150	1.1610	4500	0.1811	7250	0.0293	10000	0.0071
3160	1.1270	4550	0.1734	7300	0.0282	10050	0.0069
3170	1.0928	4600	0.1664	7350	0.0274	10100	0.0068
3180	1.0587	4650	0.1598	7400	0.0268	10150	0.0067
3190	1.0247	4700	0.1529	7450	0.0261	10200	0.0065
3200	0.9908	4750	0.1472	7500	0.0254	10250	0.0064
3210	0.9574	4800	0.1424	7550	0.0243	10300	0.0063
3220	0.9245	4850	0.1378	7600	0.0213	10350	0.0061
3230	0.8922	4900	0.1320	7650	0.0208	10400	0.0060
3240	0.8609	4950	0.1276	7700	0.0202	10450	0.0059
3250	0.8303	5000	0.1244	7750	0.0197	10500	0.0058
3260	0.8009	5050	0.1225	7800	0.0192	10550	0.0057
3270	0.7727	5100	0.1179	7850	0.0187	10600	0.0056
3280	0.7459	5150	0.1145	7900	0.0183	10650	0.0055
3290	0.7204	5200	0.1120	7950	0.0178	10700	0.0054
3300	0.6967	5250	0.1100	8000	0.0174	10750	0.0053
3310	0.6877	5300	0.1087	8050	0.0169	10800	0.0052
3320	0.6789	5350	0.1079	8100	0.0165	10850	0.0051
3330	0.6702	5400	0.1046	8150	0.0161	10900	0.0050
3340	0.6598	5450	0.1026	8200	0.0157	10950	0.0049
3350	0.6490	5500	0.1020	8250	0.0153	11000	0.0048
3360	0.6379	5550	0.1004	8300	0.0150		
3370	0.6266	5600	0.0991	8350	0.0146		
3380	0.6154	5650	0.0987	8400	0.0143		
3390	0.6042	5700	0.1001	8450	0.0139		
3400	0.5934	5750	0.0987	8500	0.0136		
3410	0.5829	5800	0.0950	8550	0.0133		
3420	0.5731	5850	0.0914	8600	0.0130		
3430	0.5640	5900	0.0887	8650	0.0127		
3440	0.5558	5950	0.0876	8700	0.0124		
3450	0.5486	6000	0.0891	8750	0.0121		
3460	0.5409	6050	0.0878	8800	0.0118		
3470	0.5337	6100	0.0844	8850	0.0115		
3480	0.5270	6150	0.0808	8900	0.0113		
3490	0.5208	6200	0.0770	8950	0.0110		
3500	0.5146	6250	0.0734	9000	0.0108		
3550	0.4830	6300	0.0702	9050	0.0106		
3600	0.4554	6350	0.0671	9100	0.0103		
3650	0.4299	6400	0.0638	9150	0.0101		
3700	0.4061	6450	0.0606	9200	0.0099		

Figure 1 Calculated Atmospheric Extinction at the Roque de los Muchachos Observatory