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TITLE: Measurements of Atmospheric Attenuation at 1.34 mm on Mauna Kea

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Measurements of Atmospheric Attenuation at 1.34mm on Mauna Kea

During the period of August 3-6, 1983, measurements of the zenith optical depth were made using a 1.34mm mixer receiver (J. Payne). In addition, during the daytime, water vapor measurements were made using the UKIRT B4 infrared meter, the NRAO Low spectral hygrometer and the IRTF Westphal spectral hygrometer. These measurements were made in conjunction with astronomical observations on the UKIRT 3.8M infrared telescope equipped with a bolometer with filter bandpasses at 1100μm, 800μm and 400μm (P. Ade).

The Equipment

The receiver consisted of a klystron and doubler for the local oscillator (224.6 GHz), quasi-optical diplexer for L.O. and signal injection into the mixer, a room temperature mixer, 4.75 GHz IF stage, a detector and DC amplifier. The receiver was operated in a load switched mode at a chopping frequency of 20-40 Hz. Two parabolic reflectors were used to narrow the beam waist down to several millimeters in order to achieve clean square wave chopping of the beam with a small chopper wheel. The second parabola rotated about the axis of the incident beam. This allowed the receiver beam to be pointed at any angle from the zenith to the horizon. The receiver temperature was 3200K(DSB). The receiver was setup outside near the entrance door to the UKIRT 3.8M telescope. It was leveled and oriented such that the beam (aimed at the horizon) pointed toward the southwest.

The UKIRT B4 infrared meter is a spectral hygrometer that compares the flux of the sun through a filter centered in the water band at 1.8μm with the flux of the sun through a filter in the continuum region at 1.7μm. The Westphal spectral hygrometer compares the solar flux in the water absorption band at .935μm with the flux at .880μm.

Radiometric Measurements

Measurements of the sky temperature at 1.34mm versus air mass (secZ) were made each day from 1300-2400 HST. The load switched receiver was calibrated using ambient absorber and absorber immersed in liquid nitrogen. The temperature of the liquid nitrogen was assumed to be 77K. This is based on a value of 80K (B. L. Ulich) used at Kitt Peak (1.91 KM) and corrected for the difference in atmospheric pressure on Mauna Kea (4.20 KM). Calibration of the receiver was done above the second (rotateable) parabola. The coupling efficiency to the hot and cold loads was assumed to be 1.0. Each set of measurements consisted of hot and cold calibration followed by sky temperature measurements at 1.0, 1.2, 1.4, 1.6, 2.0, 2.6, 3.0 air masses. A final measurement at 1.0 air mass was made to check for receiver drift (typically less than 1K). The sky temperatures were determined using a linear scale derived from the hot and cold load measurements. Since the Rayleigh-Jeans approximation is not valid at 1.34mm for very low temperatures ($h\nu/kT = 10.78/T(K)$), using a linear scale can lead to an overestimate of measured sky temperatures. The lowest measured power (radiated from the sky) corresponded to a temperature of 20K using a linearly derived scale. This amount of power actually corresponds (using a true Planck function) to a physical temperature of 19.6K. This error of .4K is smaller than the 1K drift of the receiver and does not change the determined τ values at all.

The sky temperatures versus air mass were fitted to an exponential function used to determine the zenith optical depths using the following relationship:

$$1-\frac{T_{sky}(\sec Z)-(1-\eta_L)\,T_{AMB}}{\eta_L\,T_M}=\exp^{-\tau\sec Z}$$

where $T_{sky}(\sec Z)$ = measured sky temperature at air mass = secZ

η_L = coupling efficiency to sky

T_{AMB} = ambient air temperature (K)

T_M = temperature of the atmosphere, assumed to be .95 (T_{AMB})

τ = zenith optical depth, nepers

This relationship assumes that the contribution to the sky temperature from the cosmic background is small enough to be ignored. The fitting routine used fits the data to the form y=Aexp (bx) where A should be 1.00 if the fit is perfect. The value of η_L was adjusted in some cases to make the coefficient A closer to 1. This was done only for the data taken on August 6, when the atmosphere was very dry and some small correction was needed to be made for the cosmic background.

Results

The general weather conditions over the period of observations ranged from poor to average. At the beginning of the period (Aug. 3,4), there was cumulus cloud buildup each afternoon above the Mauna Kea peak. This was the result of a hurricane which passed just north of the island of Hawaii. The weather conditions began to dry out on Aug.5 and clearly Aug. 6 was the best day of observing of the period. However, even then the conditions were not the best that Mauna Kea can produce.

Table 1 gives a summary of all measurements made. The Low water vapor values were determined using the QMC calibration curve that is used for Kitt Peak. No corrections were made for the atmospheric pressure difference between Kitt Peak and Mauna Kea. The NASA IRIF data was supplied by Ron Cohler. The water vapor values determined from Hills meter suggest a calibration error at large air masses. The values below 19 degrees elevation were consistently higher than those measured at larger elevation angles. Also all of the Hills meter values seem high compared to IRIF and Low values. A plot of the 1.34mm optical depths versus the Low water vapor values is consistent with a coefficient of 0.06 nepers/mm which is in agreement with most published values (Ulich, Astrophysical Letters, vol. 21, 1980, p 21.). There is a very poor correlation between local temperature and relative humidity and the total water vapor contained in the atmosphere. For example, for the same temperature and relative humidity on Aug. 3 and Aug. 6, the zenith optical depths were different by a factor of 2. There can also be nights when although the weather conditions seem stable (Aug. 6), the optical depth is changing continuously. This makes calibration of continuum data impossible if one relies totally on extinction data to determine the optical depth.

TABLE 1

SUMMARY OF ATMOSPHERIC MEASUREMENTS AT UKIRT (MAUNA KEA), AUG 3-6, 1983

DATE AUG	HST	AMB. AIR TEMP. K	REL. HUM. %	ZENITH OPTICAL DEPTH (τ) (NEPERS)			ZENITH WATER VAPOR (MM)		
				From Tips (224.6GHz)	From Extinction On Planets (Bolometer) 1100μM	800μM	LOW METER	HILLS METER	IRTF METER
3	1240	-	-	-			-	-	3.5
	1410	-	-	-			3.27	-	-
	1650	283	14	.196	-	-	-	5.67	-
	1810	273	18	.179			3.66	7.47*	-
	1955	274	22	.174			-	-	-
	2210	274	18	.161			-	-	
4	1300	-	-	-			-	-	2.9
	1410	288	24	.176			3.53	4.92	-
	1540	288	26	.170			3.00	5.02	-
	1735	284	21	.175	.22	.85	3.47	5.99*	-
	1940	276	28	.170			-	-	-
	2210	276	34	.185			-	-	-
	2355	276	33	.185			-	-	-
5	1435	283	25	.243			4.55	6.39	-
	1650	282	22	.169	.14-.34	.72-.97	2.27	5.80	-
	1915	276	15	.163			-	-	-
	2140	276	16	.155			-	-	-
	2355	275	70	.165			-	-	-
6	1405	282	19	.102			2.47	3.17	-
	1555	281	17	.086			2.02	2.38	-
	1730	278	19	.092	~.1	~.35	1.56	2.55*	-
	2000	274	14	.087			-	-	-
	2215	274	17	.075			-	-	-
	2325	274	19	.069			-	-	-

* Elevation of Sun ≤19°