# NASA CR- 160005

Final Report on NASA Contract NSG 5021 titled "OH and NH Emission Studies of Comet Kohoutek".

The primary purpose of this investigation was to obtain the integrated disc spectrum of the sun between the wavelengths of 3000Å and 4000Å at a resolution of about $2 \times 10^5$. This has been accomplished and will be detailed below. The second aim was to use the above mentioned spectral data to calculate the intensities of the flourescent lines of the OH radical in comets and compare the results with those obtained using center of the disc spectrum only. These calculations were also carried out and the results will be described below.

## Solar Observations

The measurements of the integrated disc spectrum of the sun (IDS) were made at the McMath Solar Telescope of the Kitt Peak National Observatory. The observations were made on 12 days, from June 2 to June 13, 1974. To obtain the IDS, a 30" flat mirror was used instead of the 60" paraboloid. The solar light was analyzed using the vacuum spectrograph in the double-pass mode. The spectra were measured in the 7th, 8th, or 9th order of the grating, depending on the wavelength. The wavelength range from 2985Å to 4061Å was covered in 134 runs, with each run covering about 10Å on the average. In each run intensity data were obtained at 4096 points (about 3mÅ apart) equally spaced in wavelength. The integration times chosen varied from about 10 min. near 4000Å to 60 minutes near 3000Å,

so that the intensities are accurate to better than 0.1%. The observed spectra were corrected for instrumental profile following the procedure described by Brault et al (1971). Within each run, the highest intensity point was chosen as the local continuum and other intensities were normalized to this value. The final relative intensities are meaningful with respect to other points in the same run only. The treated data was stored on magnetic tape and the accompanying Table I summarizes the available data. These data, properly normalized using the absolute solar flux data of Thaekaekara (1974), provide the best high resolution data to date on solar fluxes between 3000Å and 4000Å. The accuracy of absolute solar fluxes , available to date (see Thaekaekara and references therein), are nowhere near those of our relative intensities and hence we have decided not to incorporate the absolute fluxes directly into our intensity values. Copies of the data tape have been sent to a number of interested astrophysicists. Some of these investigators plan to use this for analyzing comet the near uv spectra of comets.

Application to Comets

The (0-0) band of the $^2\Sigma^+ - ^2\Pi$ transitions of OH near 3080Å is observed in comets. Recently, Mies (1974) calculated the rates for the flourescence of OH by solar uv radiation at the wavelengths of the OH lines. He found that the 3078Å doublet line intensity is higher by a factor of 4 when the

helio-centric velocity of the comet is -41 Km/ as opposed to when it is +41 Km sec. Mies used the center of the solar disc spectrum for this purpose, and further assumed that the OH molecules had no velocity dispersion. In reality, of course, the comet is illuminated by the integrated disc spectrum of the sun and the OH radicals must have some random motion. Consequently, we repeated the calculations using our IDS and incorporating velocity dispersions up to 10 Km/sec. We found that our results did not differ from those of Mies and confirms his conclusions.

The latter calculations were carried out with the assistance of a graduate student, Mr. Titus Young.

Brault, J.W., Slaughter, C.D., Pierce, A.K. and Aikens, R.S. (1971), Solar Physics, 18, 366

Mies, C.H. (1974), Ap.J. Letters, 191, L145

Thekaekara, M.P., (1974), Applied Optics, 13 518

# INTRODUCTION TO TABLE I

The spectrum of the total disk of the sun was obtained using the KPNO solar telecope and the associated vacuum spectrograph used in the double pass mode. The wavelength range covered is from 2985Å to 4061Å. The spectrum was covered in 134 steps with overlap between steps. The wavelength range 2985Å to 3353Å was observed in the 9th order, from 3309Å to 3793Å in the 8th order, and the remainder in the 7th order. In each run which covers about 10Å on the average, intensity data were obtained at 4096 points equally spaced in wavelength. The highest intensity observed in each run was set to unity and the intensities at the other 4095 points were normalized with respect to this. It is to be noted that this is a local normalization only. The observed spectrum was corrected for instrumental profile using standard KPNO procedures. The data are available on magnetic tape. The spectral resolution ($\lambda/\Delta\lambda$) is about $3 \times 10^5$.

The magnetic tape has 134 records, one for each run. Each record has a header (60A 4, 10X) followed by 4096 normalized intensity alues (F 7.4). The wavelength corresponding to each intensity value is <u>not</u> on tape but can be obtained from data in the header. The header contains superfluous data. The numbers necessary for computing the wavelength at each point and the range of each run are summarized in the table. The table gives the wavelength of the reference point and the dispersion from which the wavelength of other points can be obtained.

The table also gives the data in the order in which they appear in the tape. Copies of the tape can be obtained from C.K. Kumar, Department of Physics and Astronomy, Howard University, Washington, D.C. 20059 .

Table I

| Wavelength Range (Å) From | To | Dispersion mÅ/Point | Reference Point | Reference Wavelength (Å) |
|---|---|---|---|---|
| 2985.0718 | 2996.8623 | 2.870 | 3740 | 2995.833 |
| 2993.7191 | 3005.4388 | 2.870 | 740 | 2995.833 |
| 3002.4980 | 3014.1450 | 2.840 | 2856 | 3010.625 |
| 3011.0518 | 3022.6275 | 2.832 | 1156 | 3014.327 |
| 3019.5296 | 3031.0339 | 2.810 | 1872 | 3024.802 |
| 3028.6819 | 3040.1084 | 2.792 | 1832 | 3033.817 |
| 3037.0620 | 3048.4166 | 2.772 | 2184 | 3043.128 |
| 3045.3885 | 3056.6710 | 2.752 | 2580 | 3052.491 |
| 3053.6598 | 3064.8700 | 2.735 | 2440 | 3060.344 |
| 3061.8832 | 3073.0209 | 2.719 | 2160 | 3067.781 |
| 3070.2561 | 3081.3194 | 2.706 | 1260 | 3073.676 |
| 3078.3671 | 3089.3575 | 2.687 | 1584 | 3082.624 |
| 3086.4233 | 3097.3407 | 2.659 | 3244 | 3095.074 |
| 3094.4277 | 3105.2719 | 2.651 | 1516 | 3098.450 |
| 3102.3788 | 3113.1495 | 2.638 | 676 | 3104.164 |
| 3110.2809 | 3120.9780 | 2.606 | 3044 | 3118.252 |
| 3118.1260 | 3128.7492 | 2.597 | 1520 | 3122.074 |
| 3125.9148 | 3136.4641 | 2.571 | 2932 | 3133.485 |
| 3133.6537 | 3144.1288 | 2.565 | 860 | 3135.865 |
| 3141.3344 | 3151.7351 | 2.544 | 1412 | 3144.928 |
| 3148.8245 | 3159.1521 | 2.523 | 1948 | 3153.756 |

9th Order

Table I (Continued)

| Wavelength Range (Å) From | To | Dispersion mÅ Point | Reference Point | Reference Wavelength (Å) |
|---|---|---|---|---|
| 3156.3975 | 3166.6504 | 2.501 | 2552 | 3162.804 |
| 3163.9167 | 3174.0947 | 2.477 | 3368 | 3172.293 |
| 3171.3840 | 3181.4870 | 2.477 | 360 | 3172.293 |
| 3178.7974 | 3188.8251 | 2.440 | 3412 | 3187.159 |
| 3186.2748 | 3196.2258 | 2.436 | 1040 | 3188.823 |
| 3193.5752 | 3203.4506 | 2.412 | 2028 | 3198.479 |
| 3200.8151 | 3210.6148 | 2.389 | 2752 | 3207.412 |
| 3208.0023 | 3217.7261 | 2.366 | 3456 | 3216.215 |
| 3215.1375 | 3224.7852 | 2.366 | 456 | 3216.215 |
| 3222.0569 | 3231.6299 | 2.343 | 1152 | 3224.761 |
| 3229.0773 | 3238.5740 | 2.315 | 2688 | 3235.315 |
| 3236.0442 | 3245.4642 | 2.300 | 2160 | 3241.048 |
| 3242.9548 | 3252.2981 | 2.285 | 1544 | 3246.485 |
| 3249.8072 | 3259.0737 | 2.258 | 2792 | 3256.136 |
| 3257.2978 | 3266.4792 | 2.242 | 2100 | 3262.013 |
| 3264.0354 | 3273.1369 | 2.225 | 1796 | 3268.058 |
| 3270.7132 | 3279.7400 | 2.205 | 1892 | 3274.907 |
| 3277.3347 | 3286.2840 | 2.191 | 1212 | 3279.990 |
| 3283.8979 | 3292.7694 | 2.168 | 1728 | 3287.657 |
| 3289.5098 | 3298.3142 | 2.151 | 1924 | 3293.665 |
| 3295.9801 | 3304.7064 | 2.128 | 2456 | 3301.225 |
| 3303.1010 | 3311.7403 | 2.117 | 876 | 3304.953 |
| 3308.7306 | 3317.3004 | 2.092 | 2240 | 3313.429 |

9th Order

Table I (Continued)

| | Wavelength Range (Å) From | To | Dispersion mÅ/Point | Reference Point | Reference Wavelength (Å) |
|---|---|---|---|---|---|
| 9th Order | 3315.0155 | 3323.5069 | 2.068 | 2996 | 3321.237 |
| | 3321.2187 | 3329.6318 | 2.057 | 1728 | 3324.785 |
| | 3327.3919 | 3335.7262 | 2.035 | 2064 | 3331.617 |
| | 3333.5091 | 3341.7645 | 2.016 | 1972 | 3337.495 |
| | 3339.5713 | 3347.7477 | 1.995 | 2300 | 3344.183 |
| | 3345.5675 | 3353.6647 | 1.970 | 3120 | 3351.747 |
| 8th Order | 3309.0732 | 3322.7298 | 3.332 | 2548 | 3317.589 |
| | 3319.0865 | 3332.6646 | 3.317 | 1920 | 3325.469 |
| | 3329.0435 | 3342.5427 | 3.301 | 1380 | 3333.596 |
| | 3338.9401 | 3352.3603 | 3.277 | 2156 | 3346.018 |
| | 3348.7792 | 3362.1201 | 3.255 | 2424 | 3356.686 |
| | 3359.2627 | 3372.5184 | 3.228 | 3448 | 3370.439 |
| | 3368.9816 | 3382.1576 | 3.213 | 2792 | 3377.975 |
| | 3378.6403 | 3391.7364 | 3.197 | 2276 | 3385.945 |
| | 3388.2433 | 3401.2591 | 3.180 | 1832 | 3394.081 |
| | 3397.7872 | 3410.7226 | 3.156 | 2544 | 3405.837 |
| | 3406.6664 | 3419.5264 | 3.134 | 3056 | 3412.286 |
| | 3416.0950 | 3428.8741 | 3.114 | 3036 | 3425.580 |
| | 3425.4697 | 3438.1676 | 3.107 | 1056 | 3428.754 |
| | 3434.7801 | 3447.3976 | 3.078 | 2456 | 3442.368 |
| | 3444.0349 | 3456.5700 | 3.059 | 2384 | 3451.346 |
| | 3453.2351 | 3465.6884 | 3.041 | 2032 | 3459.431 |
| | 3462.3683 | 3474.7397 | 3.023 | 1756 | 3467.711 |

Table I (Continued)

| | Wavelength Range (Å) | | Dispersion | Reference | Reference |
|---|---|---|---|---|---|
| | From | To | mÅ/Point | Point | Wavelength (Å) |
| 8th Order | 3471.4426 | 3483.7317 | 3.000 | 2128 | 3477.860 |
| | 3480.4571 | 3492.6639 | 2.981 | 2044 | 3486.554 |
| | 3489.4121 | 3501.5363 | 2.964 | 1608 | 3494.167 |
| | 3499.8461 | 3511.8730 | 2.940 | 1560 | 3504.443 |
| | 3508.6683 | 3520.6121 | 2.913 | 2584 | 3516.219 |
| | 3517.4289 | 3529.2895 | 2.899 | 1668 | 3522.274 |
| | 3526.1273 | 3537.9044 | 2.880 | 1480 | 3530.393 |
| | 3534.7661 | 3546.4595 | 2.857 | 1872 | 3540.128 |
| | 3543.3550 | 3554.9644 | 2.835 | 1984 | 3549.007 |
| | 3551.8844 | 3563.4097 | 2.820 | 1264 | 3555.452 |
| | 3560.3373 | 3571.7783 | 2.799 | 1348 | 3564.119 |
| | 3568.7302 | 3580.0867 | 2.776 | 1680 | 3573.400 |
| | 3577.336 | 3588.3306 | 2.751 | 2272 | 3583.336 |
| | 3583.7115 | 3594.9151 | 2.737 | 1900 | 3588.924 |
| | 3591.9281 | 3603.0467 | 2.707 | 3240 | 3600.738 |
| | 3600.0856 | 3611.1190 | 2.697 | 1704 | 3604.702 |
| | 3608.1757 | 3619.1237 | 2.668 | 2808 | 3615.665 |
| | 3616.2044 | 3627.0668 | 2.649 | 2628 | 3623.192 |
| | 3624.8616 | 3635.6308 | 2.636 | 1224 | 3628.097 |
| | 3632.7571 | 3643.4404 | 2.610 | 1832 | 3637.552 |
| | 3640.5921 | 3651.1892 | 2.588 | 2016 | 3645.827 |
| | 3648.3639 | 3658.8747 | 2.570 | 1624 | 3652.548 |
| | 3656.0732 | 3666.4975 | 2.545 | 2064 | 3661.368 |
| | 3663.7391 | 3674.0764 | 2.526 | 1768 | 3668.215 |

Table I (Continued)

| | Wavelength Range (Å) From | To | Dispersion mÅ/Point | Reference Point | Reference Wavelength (Å) |
|---|---|---|---|---|---|
| 8th Order | 3671.3229 | 3681.5733 | 2.504 | 1988 | 3676.318 |
| | 3678.8510 | 3689.0143 | 2.483 | 1912 | 3683.622 |
| | 3686.3001 | 3696.3762 | 2.461 | 2028 | 3691.316 |
| | 3693.6910 | 3703.6796 | 2.441 | 1824 | 3698.166 |
| | 3700.9004 | 3710.8030 | 2.415 | 2536 | 3707.049 |
| | 3708.1692 | 3717.9840 | 2.405 | 892 | 3710.293 |
| | 3715.3704 | 3725.0972 | 2.384 | 852 | 3717.397 |
| | 3722.5049 | 3732.1436 | 2.359 | 1264 | 3725.496 |
| | 3729.5771 | 3739.1276 | 2.341 | 772 | 3731.379 |
| 7th Order | 3676.2416 | 3692.6423 | 4.011 | 1240 | 3681.230 |
| | 3688.2436. | 3704.5571 | 3.993 | 764 | 3691.314 |
| | 3700.2144 | 3716.4402 | 3.959 | 2536 | 3710.292 |
| | 3712.1091 | 3728.2471 | 3.931 | 3388 | 3725.496 |
| | 3723.9345 | 3739.9844 | 3.925 | 1204 | 3728.671 |
| | 3734.3096 | 3750.2816 | 3.903 | 1732 | 3741.065 |
| | 3746.0175 | 3761.9008 | 3.882 | 1652 | 3752.418 |
| | 3757.6619 | 3773.4563 | 3.866 | 740 | 3760.538 |
| | 3769.2366 | 3784.9418 | 3.827 | 3120 | 3781.192 |
| | 3780.7539 | 3796.3695 | 3.813 | 2080 | 3788.700 |
| | 3792.9404 | 3808.4606 | 3.784 | 2920 | 3804.015 |
| | 3804.3233 | 3819.7533 | 3.765 | 2468 | 3813.640 |
| | 3815.6390 | 3830.9787 | 3.750 | 1480 | 3821.185 |

Table I (Continued)

| | Wavelength Range (Å) | | Dispersion | Reference | Reference |
|---|---|---|---|---|---|
| | From | To | mÅ/Point | Point | Wavelength (Å) |
| 7th Order | 3838.0711 | 3853.2294 | 3.702 | 2056 | 3845.700 |
| | 3848.7817 | 3863.8522 | 3.667 | 3884 | 3863.068 |
| | 3859.8333 | 3874.8124 | 3.664 | 1224 | 3864.305 |
| | 3870.8176 | 3885.7050 | 3.642 | 1172 | 3875.079 |
| | 3881.7321 | 3896.5277 | 3.606 | 3004 | 3892.589 |
| | 3892.5863 | 3907.2897 | 3.596 | 1352 | 3897.458 |
| | 3904.2173 | 3918.8211 | 3.555 | 3512 | 3916.737 |
| | 3914.9304 | 3929.4415 | 3.555 | 516 | 3916.737 |
| | 3925.5703 | 3939.9885 | 3511 | 3332 | 3937.334 |
| | 3936.1482 | 3950.4731 | 3.498 | 2060 | 3943.346 |
| | 3946.6741 | 3960.9054 | 3.484 | 948 | 3949.959 |
| | 3956.1950 | 3970.3409 | 3.454 | 2160 | 3963.691 |
| | 3966.5483 | 3980.6005 | 3.422 | 3260 | 3977.747 |
| | 3976.8496 | 3990.8077 | 3.400 | 3152 | 3987.612 |
| | 3987.0858 | 4000.9495 | 3.392 | 1188 | 3991.121 |
| | 3997.2705 | 4011.0394 | 3.363 | 1932 | 4003.769 |
| | 4008.1805 | 4021.8469 | 3.334 | 2464 | 4016.424 |
| | 4018.2061 | 4031.7774 | 3.324 | 804 | 4020.902 |
| | 4028.1605 | 4041.6365 | 3.302 | 608 | 4030.190 |
| | 4038.0439 | 4051.4243 | 3.275 | 1100 | 4041.651 |
| | 4047.8546 | 4061.1392 | 3.246 | 1840 | 4053.824 |