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SPECTROPHOTOMETRY OF COMET KOHOUTEK (1973f) DURING PRE-PERIHELION PERIOD

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INSTRUMENTATION AND OBSERVATIONS

A total of eleven scans of the head of comet Kohoutek (1973f) were obtained during the pre-perihelion period with a photoelectric spectrum scanner (Babu, 1971), mounted at the Nasmyth focus (f/13.1) of the 52-cm telescope, on 7, 10, 11, 13, 14 and 15 December 1973 at the rate of two scans per day, except on 7 December when only one scan was taken. The observational procedure was similar to that for comet Bennett (1969 i) (Babu and Saxena, 1972), excepting that a diaphragm of 3 mm diameter equivalent of 93" of the sky was used at the entrance of the monochromator. The width of the exit slit was equivalent to a spectral window of 3.5 nm. The scans covered the spectral range from 370 to 640 nm. The basic data of the comet during the period of observations is given in Table I.

In addition, two late type stars, π Hya (K2 III) and β Crv (G5 III) were observed on each night to serve as comparison stars. Since β Crv is suspected to be a variable (Hoffleit, 1964), π Hya has been chosen as the comparison star.

The reduction technique is same as that used in the case of comet Bennett (loc. cit.) where all the measurements were normalised to 479 nm. In order to get the normalised relative magnitudes of the comet at each wavelength, the

TABLE I

Basic data of comet Kohoutek (1973f)

Date Dec.1973 U.T.	Δ (in a.u)	r (in a.u.)	Phase angle	m	Area of the sky at distance Δ admited through diaphram (in sq.km)	Radius of the circular region in sky at dist. Δ (in Km)
7.003	1.262	0.733	51.2°	$+3.1^m$	56.72×10^8	4.249×10^4
10.011	1.217	0.655	53.8°	$+2.5^m$	52.72×10^8	4.097×10^4
11.013	1.204	0.628	54.6°	$+2.3^m$	51.62×10^8	4.053×10^4
13.015	1.181	0.573	56.1°	$+1.9^m$	49.68×10^8	3.976×10^4
14.005	1.171	0.545	56.7°	$+1.7^m$	48.84×10^8	3.942×10^4
15.011	1.163	0.516	57.3°	$+1.3^m$	48.17×10^8	3.915×10^4

differential magnitudes (comet- π Hya)λ were obtained and then converted into intensities.

RELATIVE FLUX DISTRIBUTIONS

Figure 1 shows the mean relative flux distributions of the head of comet Kohoutek (1973 f) on various dates, the vertical lines showing the probable errors. In these the emission features of CN, C_3, CH, the principal Swan band sequences of C_2 and Na have readily been identified. After locating the continuum in the scans, (Swings and Haser, 1956), the areas of the emission band profiles were planimetered. The probable errors in these measurements are found to be less than 5%. These areas, which are identified with the total band intensities, are given in Table II along with the continuum intensities at 479 nm relative to the C_2 ($\Delta V = 0$) band sequence at 516 nm. The total energies streaming out of a cylinder with diameter corresponding to the diaphragm size and extending through the entire comet along the line of sight in C_2 ($\Delta V = 0$) band along with the observed fluxes are also given in the same table. The reduction was made by multiplying the observed flux by $4\pi\Delta^2$ (O'Dell and Osterbrock, 1962).

It is clear from this table that the intensity of Na emission steadily increased with the decreasing r during our observational period. This is similar to the case of comet Ikeya-Seki (1965 f) (Bappu and Sivaraman, 1967). However, it has been reported by Bappu et al. (1973) that in comet Kohoutek (1973 f) the Na emission was first noticed on 8.98 December 1973. But our observations show that Na was in emission even on 7.003 December 1973, though very faintly.

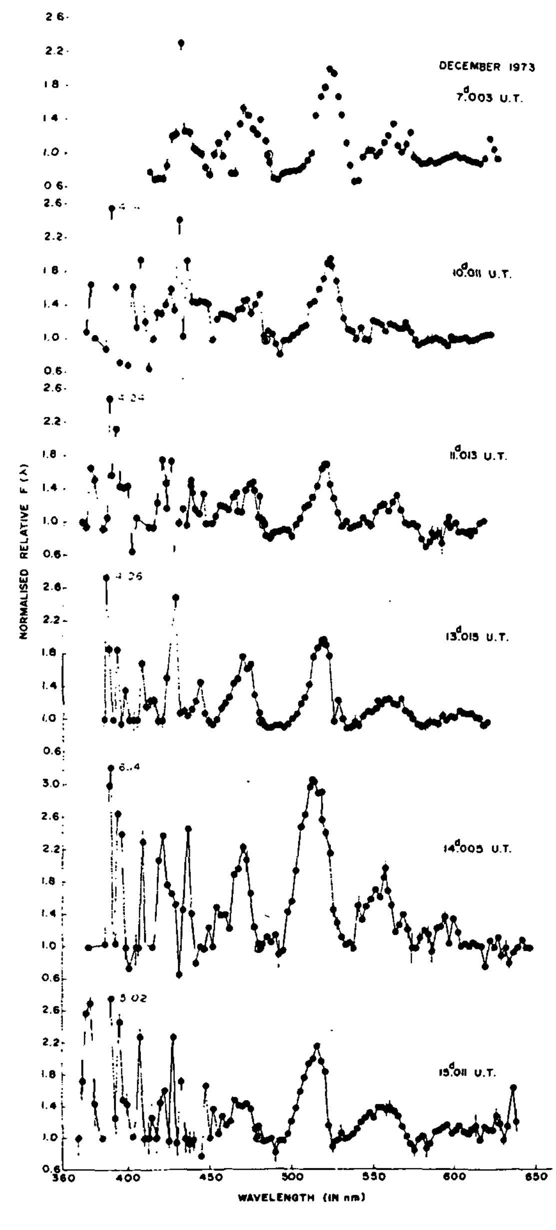

Figure 1: Relative flux distributions of the head of comet Kohoutek (1973 f) on various dates normalised to λ479 nm. The normalisation point is shown as a circle with a dot. Intensity at CN (λ388 nm) is reduced to fit the plot and is given by the numbers adjacent to the peak. The vertical lines denote the limits of errors.

TABLE II
Relative fluxes of emission band sequences and continuum in the head of Comet Kohoutek (1973f)

Date Dec. 1973 U.T.	Apparent $F(C_2, \Delta V=0)$ (ergs cm^{-2} sec^{-1})	$F/F(C_2, \Delta V=0)$								$4\pi\Delta^2 F(C_2, \Delta V=0)$ (ergs sec^{-1})
		CN (388 nm)	C_3 (405 nm)	CH (428 nm)	C_2 $\Delta V=-1$ (474 nm)	C_2 $\Delta V=0$ (516 nm)	C_2 $\Delta V=+1$ (563 nm)	NA (588 nm)	Continuum (479 nm)	
7.003	2.164×10^{-7}	1.036	-	0.181	0.446	1.000	0.271	0.007	0.516	9.696×10^{20}
10.011	4.919×10^{-7}	0.745	0.093	0.180	0.652	1.000	0.317	0.009	0.566	4.753×10^{21}
11.013	2.173×10^{-7}	0.644	0.110	0.188	0.665	1.000	0.414	0.042	0.622	2.055×10^{21}
13.015	7.305×10^{-7}	0.638	0.110	0.476	0.693	1.000	0.440	0.081	0.535	6.647×10^{21}
14.005	9.369×10^{-7}	0.497	0.118	0.247	0.536	1.000	0.435	0.084	0.344	8.382×10^{21}
15.011	11.459×10^{-7}	0.448	0.146	0.174	0.700	1.000	0.496	0.104	0.543	1.011×10^{22}

Dobrovolskii (1961) has pointed out that the emissions due to C_2 and C_3 are less dependent on r when $r<1.5$ a.u.. Since all our observations are obtained when r was less than 1.0 a.u., the fluxes due to these two homonuclear molecules are expected to be nearly constant as r decreased. But, in the present case, the absolute flux of C_2 emission at 516 nm and even the relative fluxes of C_2 emissions at 474 nm and at 563 nm show an increase with the decrease in r. Similar is the case with the C_3 emission at 405 nm. This is akin to the case of comet Rudnicki (1966 e) (Mayer and O'Dell, 1968). This increase in the fluxes can be explained only in terms of an increase in the abundances of C_2 and C_3 in the head of the comet due to some internal processes which depend on r.

The relative intensity in the CN band at 388 nm shows a steady decrease with decreasing r. This behaviour matches that of comet Bester (1947 k) (vide Swings, 1965).

The relative continuum intensities at 479 nm are weaker than those found in comet Ikeya-Seki (1967 n), Honda (1968 c) and Thomas 1968 b) as given by Gebel (1970). Even the relative continuum intensities of comet Bennett (1969 i) (vide Babu and Saxena, 1972) were stronger than the present values. Nevertheless comet Kohoutek (1973 f) is not void of continuum, thereby showing the presence of dust particles.

CONTINUUM ENERGY DISTRIBUTIONS

The continuum energy distributions in the head of comet Kohoutek (1973 f) on different dates along with those of π Hya and β Crv have been obtained independently, using γ Gem as a standard star. The calibration of γ Gem was taken from Wolff et al. (1968). The adopted monochromatic values relative to 479 nm are given in Table III and are plotted in Figure 2. The energy distribution of the sun (Arpigny, 1965) is also plotted in the same figure.

On 7 December, when the phase angle was about 51°.2, the energy curve of the comet is found to fall around midway between those of β Crv (G5 III) and the Sun (G2 V). On the later dates, as the phase angle increased, the energy curves of the comet approached that of Sun. During the last three days of our observations, they were found to nearly coincide with that of the Sun. It may be noted here that the phase angle of 57°.3 on 15 December was very close to the preperihelion maximum value of 57°.8 on 17 December. Thus the reddening of the scattered light coming from the head of the comet decreased as the phase angle increased, relative to the energy curve of sun, which compares with the case of Comet Bennett (Babu and Saxena, 1972). However, we have no usable observations available to us to study if this trend continued or not with comet Kohoutek after the comet went past its maximum phase angle on 17 December.

TABLE III

Adopted monochromatic magnitudes of comet Kohoutek (1973f), π Hya, β Crv and Sun normalised to 479 nm

Wavelength (in nm) / Date Dec.1973 U.T.	370	447	479	535	615	Name of the object
	m	m	m	m	m	
7.003	+0.544	-0.065	0.000	+0.087	+0.086	Comet Kohoutek (1973f)
10.011	+0.398 ±0.20	-0.085 ±0.12	0.000	+0.107 ±0.08	+0.116 ±0.12	
11.013	+0.491 ±0.02	-0.022 ±0.18	0.000	+0.130 ±0.05	+0.229 ±0.07	
13.015	+0.256 ±0.25	-0.025 ±0.10	0.000	+0.167 ±0.04	+0.426 ±0.08	
14.005	+0.348 ±0.10	-0.121 ±0.20	0.000	+0.158 ±0.04	+0.374 ±0.05	
15.011	+0.262 ±0.25	-0.122 ±0.00	0.000	+0.215 ±0.03	+0.478 ±0.10	
	+1.012 ±0.15	+0.272 ±0.06	0.000	-0.261 ±0.02	-0.635 ±0.03	π Hya
	+1.544 ±0.08	+0.250 ±0.02	0.000	-0.211 ±0.01	-0.446 ±0.01	β Crv
	+0.51	-0.05	0.000	+0.15	+0.43	Sun

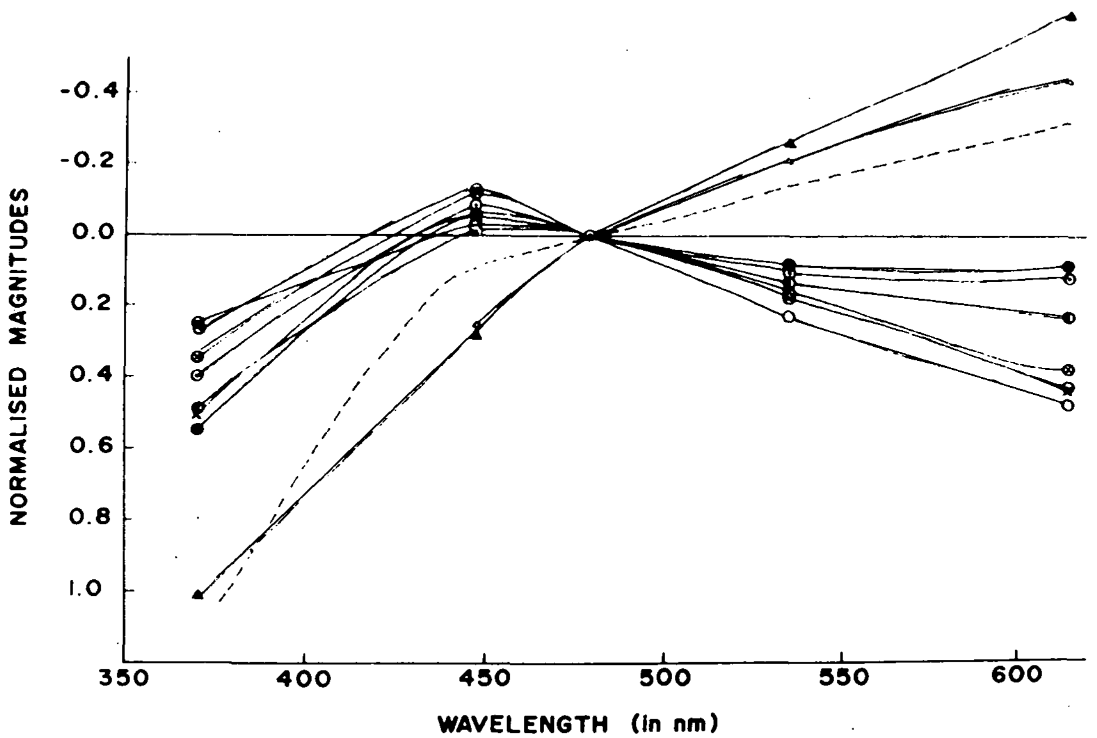

Figure 2: Continuum energy distribution curves of the head of comet Kohoutek (1973 f), which are denoted by circles in the following manner: ● for 7.003 December, ⊙ for 10.011 December, ◐ for 11.013 December, ⊖ for 13.015 December, ⊗ for 14.005 December and O for 15.011 December, 1973, compared with those of πHya (▲), βCrv (△), Sun (X) and solar light scattered according to λ^2 law (------). All curves are normalised to 479 nm and the Balmer discontinuity is smoothed out.

In the previous studies, however, some comets are known to have had a pure reflection continuum, in the sense that the continuum spectra were unreddened with respect to that of the Sun (Arpigny, 1965; Gebel, 1970), whereas some others were found to produce reddened scattered continuous spectra matching those of late type stars around G8 (Bappu and Sinvhal, 1960; Kharitonov and Rebristyi, 1974; Liller, 1960; Vanýsek, 1960; Walker, 1958).

Arpigny (1965) has pointed that the dust grains in comets possibly have a certain range of sizes and the predominant size could be different in different comets. This could produce both reddened and unreddened scattered continuous spectra in the respective comets. Also, assuming dielectric particles and a narrow distribution function of sizes, the selectivity of scattered light depends strongly but not monotonously on the phase angle*. But, it is not known whether the size distribution function and the predominant particle size are varying or not in a given comet along its path around the sun.

To find out the effect due to the variations in the physical parameters only on the intensity in a particular wavelength, the phase angle effect must be separated out from the total. We believe, in principle, it is possible to use appropriate scattering functions for various size distributions of particles and find out the variation of the intensity at a particular wavelength in a given phase angle. This being a complicated program, the same has not yet been attempted.

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