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THE SPECTRUM OF COMET 1948l*

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ABSTRACT

Eight spectrograms of Comet 1948l, covering the range of heliocentric distances from 0.65 to 2.21 A.U., have been obtained. Sodium emission is observed at $r = 0.73$ and $r = 0.79$ A.U. At large heliocentric distances ($r = 2.21$) only CN and the λ 4050 group are observed. The CN bands show the usual complex structure due to the fluorescence excitation by solar radiation. The behavior of CH and that of CH_2 are compared. Unidentified features are present within and between the Swan bands, as well as in the yellow-red region.

Progress in cometary physics depends to a great extent on the solution to the following problems:

a) Is the λ 4050 group really and exclusively due to CH_2? Recent laboratory work by A. Monfils and B. Rosen,[1] Mme R. Herman,[2] and others and observational work by C. Fehrenbach[3] and B. Rosen[4] have definitely raised the question.

b) Is the λ 6300 group really and exclusively due to NH_2? The cometary observations by Swings, McKellar, and Minkowski,[5] J. Dufay,[6] C. Fehrenbach,[7] and Swings and Page,[8] combined with numerous laboratory investigations,[9] indicate that the cometary emission in the visual region is probably not due entirely to NH_2.

c) What are the molecules responsible for the emissions observed[10] in various comets within and between the Swan sequences of C_2?

d) What is the physical relation between the CH_2 and CH molecules?

Actually, the answers to questions *a*, *b*, and *c* also have a direct bearing on our knowledge of the stars of the latest types. Recent work by McKellar and Swings[11] has led to the tentative identification of CH_2 in the N stars. The NH_2 bands may be expected in the latest M or N stars. As for the molecules responsible for the unidentified emissions in the region of the Swan bands, they may be of interest in relation with the unidentified absorptions found in the N stars, as discussed most recently by V. Hase and G. Shajn.[12]

The bright Comet 1948l provided an opportunity for securing additional observational material pertaining to the above-mentioned questions. Eight spectrograms were obtained during the period from November 14, 1948, to February 2, 1949, using various types of spectrographs attached to the Cassegrain focus of the McDonald reflector. All

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* *Contributions from the McDonald Observatory, University of Texas*, No. 176.

[1] *Nature*, **164**, 713, 1949, and private communication.

[2] *C.R.*, **223**, 221, 1946; **227**, 962, 1948; **228**, 1691, 1949.

[3] *C.R.*, **227**, 519, 1948.

[4] Private communication.

[5] *Ap. J.*, **98**, 142, 1943.

[6] *C.R.*, **222**, 51, 1946.

[7] Private communication.

[8] *Ap. J.*, **108**, 526, 1948.

[9] See references in Swings, McKellar, and Minkowski (n. 5).

[10] N. T. Bobrovnikoff, *Ap. J.*, **99**, 173, 1944, and *Pub. Lick Obs.*, **17**, 436, 1931; Swings and Page, *loc. cit.*

[11] A. McKellar, *Ap. J.*, **108**, 453, 1948; P. Swings and A. McKellar, *Ap. J.*, **108**, 458, 1948; P. Swings and K. N. Rao, unpublished.

[12] *Pub. Crimean Ap. Obs.*, Vol. **2**, 1948.

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these spectrograms are of good quality, except that of December 30, which is a little weak. They cover the region λλ 3300–6600. The heliocentric distances extend over the unusually wide range from $r = 0.65$ to $r = 2.21$ A.U. The comet had passed perihelion on October 27.4, the perihelion distance being relatively small, 0.14 A.U. All the spectroscopic observations were thus made after perihelion passage, as in the case of the previous bright Comet 1947n.[8] The absolute magnitude of Comet 1948l is approximately $M = 5.9$, hence almost equal to that of the preceding bright Comet 1947n ($M = 6.2$). These two objects are of only average luminosity, since absolute magnitudes from 0 to 15 have been observed; they owed their temporary high brightness to their proximity to the sun. The essential observational data are summarized in Table 1

TABLE 1

SPECTROGRAMS OF COMET 1948l OBTAINED AT THE MCDONALD OBSERVATORY

DATE (U.T.)	HELIOCENTRIC DISTANCE, r (IN A.U.)	RADIAL VELOCITY RELATIVE TO SUN (dr/dt IN KM/SEC)	CAMERA	DISPERSION IN A/MM AT			PROJECTED SLIT-WIDTH IN A AT			EMULSION	EXPOSURE TIME (MINUTES)
				λ 3880	λ 4700	λ 6000	λ 3880	λ 4700	λ 6000		
1948											
Nov. 14.506...	0.648	46.7	CQ	38	70	......	0.95	1.75	......	103*a*-O	32
17.496...	0.728	44.8	Q*f*/2	115	216	450	2.07	3.90	8.10	103*a*-E	70
19.503	0.778	43.2	G*f*/2	45	104	247	0.81	1.87	4.45	103*a*-E	80
24.500...	0.900	40.6	G*f*/2	45	104	247	0.81	1.87	4.45	103*a*-E	90
28.507...	0.999	39.3	G*f*/1	89	208	490	1.21	2.81	6.61	103*a*-E	70
Dec. 2.500...	1.081	37.5	G*f*/1	89	208	490	1.21	2.81	6.61	103*a*-E	60
30.354...	1.634	31.1	Q*f*/1	230	432	900	3.11	5.83	12.3	103*a*-E	60
1949											
Feb. 2.266...	2.209	27.3	Q*f*/1	230	432	......	4.14	7.76	......	103*a*-O	120

GENERAL DESCRIPTION OF SPECTRUM AND BEHAVIOR WITH HELIOCENTRIC DISTANCES

All the spectrograms were taken by guiding as accurately as possible on the nucleus, which had a stellar appearance. It is thus possible to obtain a picture of the distribution of the different emitting molecules within the head. The solar spectrum reflected by the nucleus is strong on all exposures. Comet 1948l is not so favorable as several others for the detection of emissions localized near the nucleus.

The D doublet of sodium appears clearly on the spectrograms of November 17 ($r = 0.73$) and 19 ($r = 0.78$). On November 17, the D emission is long, partly due to twilight, but is strongly enhanced in the nucleus. On November 19 the emission is purely nuclear; its double character could be measured accurately. The D emission does not appear at heliocentric distances greater than 0.78.

No spectrogram covers the region of the OH band. The NH band appears on the spectrogram of November 17 ($r = 0.73$), but is unusually weak. The (1, 0) band of the violet system of CN is not seen with certainty on any spectrogram. On two strong exposures ($r = 0.73$ and $r = 0.78$) the $^2\Sigma \rightarrow {^2\Pi}$ system of CH appears clearly as nuclear emission on the longward side of the strong CN band at λ 3880. On account of the intense solar spectrum, no conclusive evidence is found for CH^+, although λ 4254 seems to be present for $r = 0.73$ and $r = 0.78$.

As appears clearly in Figure 1, the CN emission extends into the head much farther

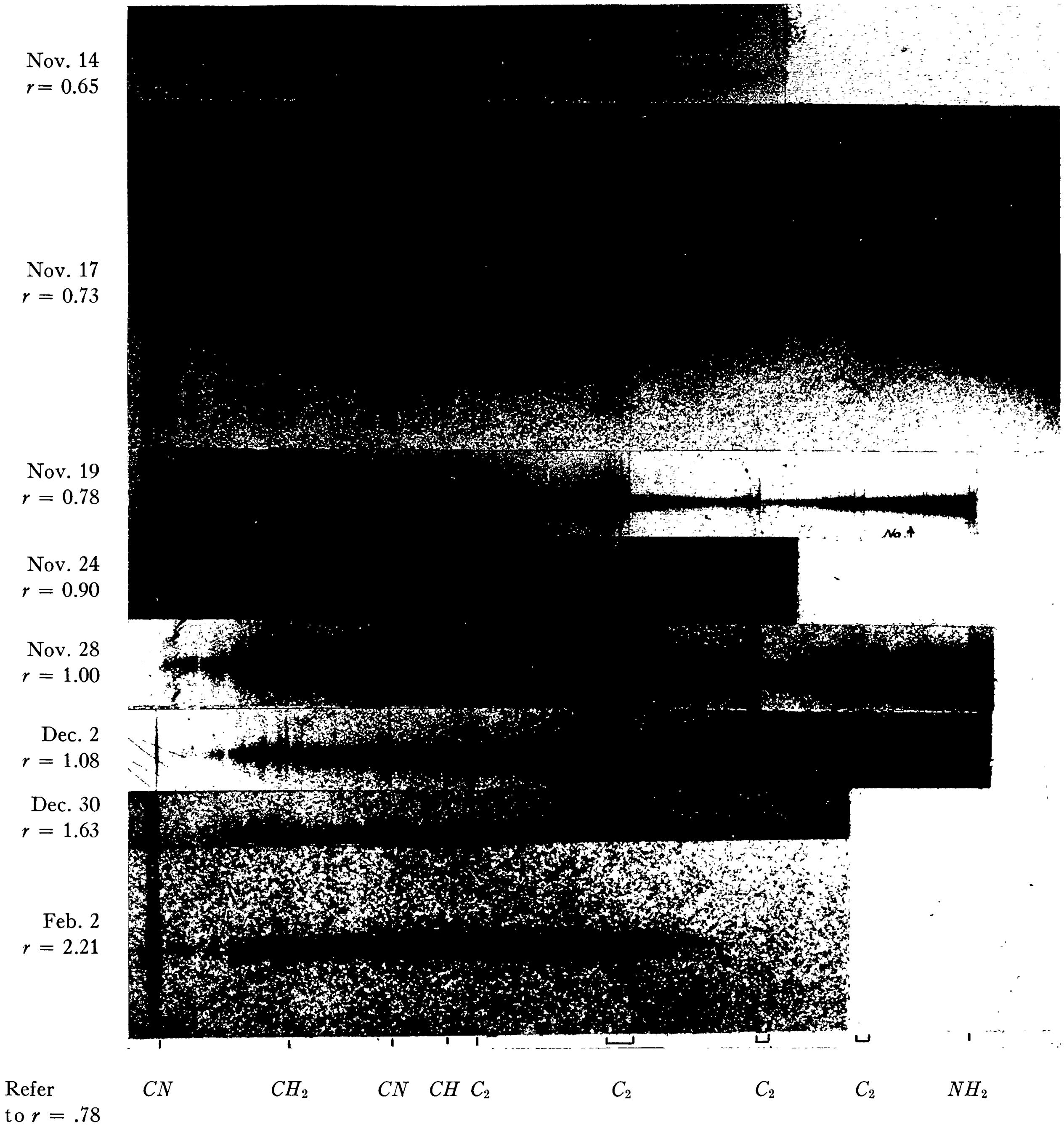

FIG. 1.—General evolution of the spectrum of Comet 1948l

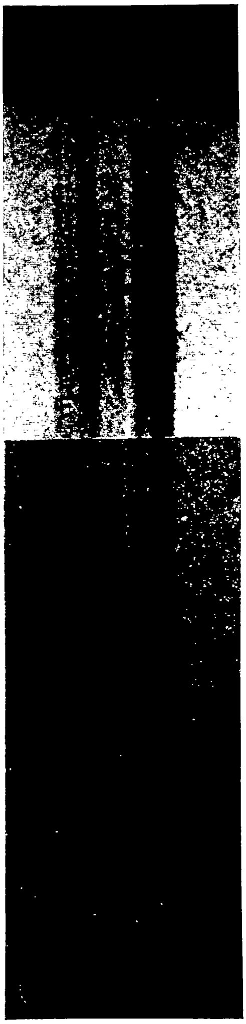

FIG. 2.—Structure of the (0, 0) band of *CN*

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than does C_2. Actually, the intensity gradient along a *CN* line (as a function of distance from the nucleus) is smoother than along a C_2 band; this appears especially well on the spectrograms taken at $r = 0.73$ and $r = 0.78$. The intensity of C_2 decreases steadily, relative to *CN*, when r decreases. At $r = 0.78$ the head of the (0, 0) band of C_2 has, near the nucleus, approximately the same intensity as does the head of the (0, 0) band of *CN*. The strongest C_2 bands have practically disappeared at $r = 1.63$, and no trace of the (1, 0) band is left at $r = 2.21$.

At large heliocentric distances the only remaining conspicuous features in the region λλ 3800–5000 of the spectrum are *CN* and the λ 4050 group (see spectrogram at $r = 2.21$; cometary spectra have rarely been obtained at such large heliocentric distances). As has been emphasized in previous papers, the λ 4050 group increases steadily in intensity relative to all other molecules (except possibly the λ 6300 group)[13] when r increases. The present observations show that this intensity increase of the λ 4050 group takes place to $r = 2.21$ at least. At this large heliocentric distance λ 4052 is about as strong as the *R* branch of *CN* (0, 0) in the nuclear region. The considerable extension of *CN* stands in conspicuous contrast to the shortness of λ 4052 at $r = 2.21$.

The relative intensity behavior of *CH* and CH_2 is also clearly illustrated in Figure 1. For $r \leqslant 0.78$, λ 4313 *CH* is as strong as, or stronger than, λ 4052. The intensity ratio of *CH* and CH_2 declines steadily with increasing r; *CH* is still very weakly present for $r = 1.63$ but has practically disappeared for $r = 2.21$.

A similar comparison applies to C_2 and CH_2 or to *CN* and CH_2. For $r = 1.00$, λ 5165 C_2 is still stronger than λ 4052 but becomes weaker for $r > 1.0$. Similarly, the (0, 1) band of *CN* is stronger than λ 4052 for $r \leqslant 0.78$ but has become very weak compared with λ 4052 for $r = 2.21$.

The guiding was accurate enough for obtaining estimates of the extensions of the head in different molecules. However, the slit was not long enough to cover all the *CN* emission, so that only minimum values are obtained for this molecule. Measures made on the spectrograms of November 24, 1949 ($r = 0.90$), and February 2, 1949 ($r = 2.21$), give the following figures.

For $r = 0.90$: Diameter of *CN* $> 62{,}000$ km;
Diameter of $CH_2 \simeq 4140$ km.
For $r = 2.21$: Diameter of *CN* $> 166{,}000$ km;
Diameter of $CH_2 \simeq 22{,}000$ km.

The ratio of the diameters of CH_2 emission at $r = 2.21$ and $r = 0.90$ is 5.3, which is close to the square of the ratio of the heliocentric distances $(2.21/0.9)^2 = 6.03$. The contraction of the CH_2 zone, as the comet approached the sun, was proportional to r^2, as is required by Wurm's theory.[14] The preceding figures also illustrate the fact that the zone of CH_2 emission has a volume of the order of 3×10^{-4} that of the zone of *CN* emission or less.

STRUCTURE OF THE VIOLET CYANOGEN BANDS

The best spectrograms in the *CN* region, i.e., at $r = 0.65$ and $r = 0.78$, have been measured directly at the comparator and also on microphotometer tracings. The projected slit widths at λ 3880 are, respectively, 0.95 A for $r = 0.65$, and 0.81 A for $r = 0.78$. For $K'' > 11$ the separations between the rotational lines of the *R* branch are larger than 0.81 A, so that individual rotational lines should be observable.[15] Moreover, certain rotational lines may be reduced in intensity on account of Fraunhofer absorptions in the exciting solar radiation; this helps in bringing out individual rotational lines of the *R*

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[13] The spectrogram obtained at $r = 1.63$ has poor definition in the red; for $r = 2.21$ the visual region was not covered.

[14] *Mitt. Hamburger Sternw. Bergedorf*, 8, No. 51, 74, 1943, and references indicated in this paper.

[15] For a still higher resolution of the *CN* band see A. McKellar, *Ap. J.*, 99, 162, 1944.

branch. Of course, the lines of the P branch are too closely packed to be separated ($\Delta\lambda <$ 0.54 A).

The measurements of the two spectrograms are in excellent agreement, although slight differences in the profiles are present. Since the radial velocity of the comet relative to the sun varies but slightly from $r = 0.65$ to $r = 0.78$, bringing about a shift of only 0.04 A in the exciting radiation, the change in the intensity distribution must be essentially due to a change in the rotational temperature of the *CN* molecules.

Figure 1 shows how strikingly the *CN* profile varies from $r = 0.65$ to $r = 2.21$. While some effect of the radial velocity certainly takes place over the wide range of heliocentric distances (from $r = 0.65$ to $r = 2.21$ the exciting radiation shifts by about 0.25 A), the main systematic variation in profile of *CN* is due to the decrease in rotational temperature. This point has been dwelt upon at length on previous occasions and will not be considered here again. Figure 2 shows the structures of the (0, 0) band of *CN* at $r = 0.65$ and $r = 0.78$. The results of the measurements are collected in Table 2.

The strongest feature is the part of the P branch from $P(9)$ to $P(22)$. Next in intensity is the group from $P(3)$ to $P(6)$, which is separated from the blend $P(9)$ to $P(22)$ by a deep minimum centered at $P(7)$. In the R branch several maxima and minima are due to blends, but there are also sharp individual rotational lines, for example, $R(13)$ and $R(16)$. Fairly high values of K'' (at least $K'' = 19$) are observed in the R branch, as is customary at small heliocentric distances. As a comparison, consider the case of Comet 1942g in which McKellar observed a maximum value of $K'' = +14$; the heliocentric distance was approximately 1.4 A.U. On our spectrogram for $r = 2.21$ the maximum K'' must be approximately 10 or even less.

While there is no doubt that the P branch is exclusively due to the (0, 0) transition of *CN*, a contribution of the (1, 1) transition is not excluded within the R branch of (0, 0). The origin of (1, 1) is at λ 3863.0. If, as is likely, the general rotational intensity distribution within the P and R branches of (1, 1) is the same[16] as within (0, 0), the maximum of the $P(1, 1)$ branch should arise around λ 3869, that of $R(1, 1)$ around λ 3857. It has been customary to neglect the possible effect of (1, 1), which doubtless is rather minor on account of the low vibrational temperature of the violet system of *CN*. However, it is not certain that the weaker features observed to the violet of λ 3859 are not partly due to (1, 1). The P branch of (1, 1) may also fill in the region around λ 3869 with a weak background of emission.

One may gather some information regarding the intensity of the hypothetical (1, 1) band by considering the (1, 0) transition at λ 3590. This (1, 0) band is not clearly present on any spectrogram of Comet 1948l, but it has been observed previously, for example, in Comet Cunningham.[17] The intensity ratio of the (1, 0) and (1, 1) transitions which arise from the same excited level should remain constant and equal to the ratio of the emission transition probabilities.[18] The theoretical[19] and laboratory[20] values of these probabilities agree to give to the (1, 1) band an intensity of from five to nine times that of the (1, 0) band.

It appears likely that the weak shortward intensity of the *CN* emission is due to the R branch of (1, 1), possibly with some contribution added by R lines of high K number

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[16] Not considering the sharp minima due to the solar absorption lines.

[17] Swings, Elvey, and Babcock, *Ap. J.*, **94**, 320, 1941; P. Swings, *Ap. J.*, **95**, 270, 1941.

[18] Similarly, the (0, 0) and (0, 1) bands have a definite intensity ratio. But direct intensity comparisons between (0, 0) and (1, 0) or (1, 1) are precarious because the excited levels are not the same and the vibrational temperature plays an important role.

[19] Computed by A. McKellar and W. Buscombe, *Pub. Dom. Ap. Obs. Victoria*, **7**, 361, 1948, from theory developed by E. Hutchisson, *Phys. Rev.*, **36**, 410, 1930.

[20] Ornstein and Brinkman, *Proc. Kon. Akad. Wetensch., Amsterdam*, **34**, 33, 1931. In Pearse and Gaydon's *The Identification of Molecular Spectra* (London: Chapman Hall, Ltd., 1941), p. 76, the estimated intensities do not differ greatly: (1, 0), int. 8; (1, 1), int. 9.

($K'' = 20$–27) of (0, 0). At any rate, the (1, 1) transition is certainly very weak compared with (0, 0). A similar result has been obtained for Comet Cunningham,[21] in which weak lines measured at λλ 3852.0, 3854.0, and 3857.7 were attributed to the $R(7)$–$R(15)$ lines of the (1, 1) transition.

The two separate emissions at λ 3867.1 and λ 3869.2, which are blends of several R lines, arise on account of the effect of the solar absorption lines on the fluorescence pattern.[22] The whole space between λ 3867.1 and λ 3869.2 contains some weaker emission. On one plate the line at λ 3869.2 seems to show two maxima, at λ 3868.2 and λ 3869.7, respectively; these correspond to $R(9)$ and $R(7)$, respectively. In the emission at λ 3872.1, $R(3)$ and $R(5)$ contribute; $R(3)$ may also contribute in the emission appearing at λ 3873.5. All these contributions are affected by the profile of the exciting solar radiation.

TABLE 2

STRUCTURE OF THE (0, 0) BAND OF CN

Int.	λ	Identification Notation		Remarks
1 from	3851.0			Wide weak emission with structure
to	3854.2	$R(20)$–$R(27)$ of (0, 0)		
		plus		
0-1	3857.69	$R(7)$ –$R(16)$ of (1, 1)		
1-0	3858.35			Separation difficult
1	3859.40	$R(19)$	59.67	
Minimum	3860.60	$R(18)$	60.63	$R(17)$ is also weak
3s	3862.41	$R(16)$	62.49	Individual rotational line
5	3863.40	$R(15)$	63.38	Wider than λ 3862.4 and λ 3865.1
Minimum	3864.22	$R(14)$	64.30	
4s	3865.07	$R(13)$	65.15	Individual rotational line
Minimum	3865.89	$R(12)$	65.99	
4n	3867.12	$R(11)$	66.82	
		$R(10)$	67.62	
6n	3869.21	$R(9)$	68.41	
		$R(8)$	69.18	
		$R(7)$	69.92	
Minimum	3871.17	$R(6)$	70.67	
		$R(5)$	71.37	
3n	3872.12	$R(4)$	72.06	Some contribution of $R(5)$ and $R(3)$
4n	3873.50	$R(2)$	73.36	Some contribution of $R(3)$
		$R(1)$	74.00	
Deep min	3875.16	Origin	75.20	
7 from	3876.5			
		$P(4)$	77.35	Contributions of $P(3)$, $P(5)$, $P(6)$
to	3878.4			
Minimum	3878.87	$P(7)$	78.75	Also $P(8)$
from	3879.6	$P(9)$	3879.58	
to	3883.0	$P(22)$	3882.99	
Max. 10n	3880.46	$P(11)$	80.33	Contributions from $P(9)$–$P(22)$
Min	3881.62	$P(14)$	81.32	
		$P(15)$	81.59	
		$P(16)$	81.88	
Max. 15s	3882.02	$P(17)$	82.10	

The observed intensity distribution among the rotational lines is in complete agreement with the fluorescence mechanism.[22] The intensity minima in the R branch at K'' =

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[21] P. Swings, *Lick Obs. Bull.*, **19**, 131, 1941.

[22] *Ibid.*, and *M.N.*, **103**, 86, 1943; A. McKellar, *Rev. Mod. Phys.*, **14**, 179, 1942.

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14, 12, and 6 + 5 correspond, as they should, to the minima at $K'' = 16$, 14, and 8 + 7 in the *P* branch. They are due to absorption lines in the exciting solar radiation shifted appreciably by radial velocity.

On one of the spectrograms the (0, 1) band shows a doubling of the *P* head, of the same type as in the (0, 0) band. The two intensity maxima correspond roughly to the same values as K'' as in the (0, 0) transition. Actually, all the rotational intensity distributions appear similar, although such a comparision is difficult and somewhat precarious on account of the considerable difference in intensity between (0, 0) and (0, 1). This is in agreement with the fluorescence theory, according to which the rotational intensity distributions arise from the population distributions among the excited rotational levels, as due to absorption of the complex solar radiation. The (0, 0) and (0, 1) bands have the same upper levels, hence should reveal similar rotational intensity distributions.

THE λ 4050 GROUP

The emission lines around λ 4050 definitely are not so sharp as are the individual *CH* or *CN* lines; they are not individual rotational lines of a molecule but, rather, narrow bands or blends. The emission lines have been measured on the best spectrograms; the wave lengths are in perfect agreement with those previously listed. The doubling of λ 4052 which McKellar observed in Comet 1942g (λ 4050.43 and λ 4051.75) cannot be seen clearly on our present spectrograms; this doubling corresponds to the two laboratory emissions measured by Mme R. Herman at λ 4049.9 and λ 4051.9. On one of our spectrograms we suspect a satellite, 1.2 A to the red of the strong λ 4043 line; however, the presence of a strong solar spectrum makes such a detection difficult and uncertain. Since Herzberg's work[23] it has been customary to attribute the λ 4050 group to the triatomic CH_2 radical, and there are excellent astronomical reasons favoring such an identification.[24] However, Herzberg[25] himself occasionally mentioned that the identification of CH_2 is still hypothetical and that some other molecule, such as C_2H, may also be considered possible.

The most recent laboratory work by A. Monfils and B. Rosen[1] on the fine structure of the main λ 4052 band leads to a moment of inertia which is too high for a molecule such as CH_2. This experimental investigation does not exclude the possibility that two different molecules[26] may take part in the emission around λ 4050.[27]

Fehrenbach[3] has suggested that λ 4013 and λ 4067 are too strong in Comet 1948g, compared with the laboratory, and that an emission other than CH_2 overlaps in the same region. The spectrograms of Comet 1948l do not seem to necessitate such an additional emission; λ 4013 and λ 4067 are not very strong (Fig. 3). It should be borne in mind that the profile of the CH_2 emission may, like that of *CN*, *CH*, *OH*, or *NH*, be sensitive to heliocentric distance and radial velocity. It may be understandable that different intensity distributions within the λ 4050 group could be present in different comets, or in the same comet at different heliocentric distances. For example, the intensity ratio of λ 4074 and λ 4043 may be influenced by the strong *Fe* I solar lines, in different degrees according to the radial velocity. Yet in Comet 1948l no striking difference is observed between the CH_2 profiles at $r = 0.7$ and $r = 2.2$, when proper account of the different resolutions is taken.

It is possible that a systematic examination of the intensity distribution within the

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[23] *Ap. J.*, **96**, 314, 1942.

[24] P. Swings, *Rev. Mod. Phys.*, **14**, 190, 1942; *M.N.*, **103**, 86, 1943

[25] Private communication; see McKellar, *Ap. J.*, **108**, 456, 1948; T. L. Page, *Pub. A.S.P.*, **60**, 249, 1948.

[26] However, it remains true that the previously considered molecules, such as *NaH*, OH^+, *CH*, etc., are excluded for the interpretation of the λ 4050 group.

[27] In the present paper we have assumed that the λ 4050 group is due to CH_2.

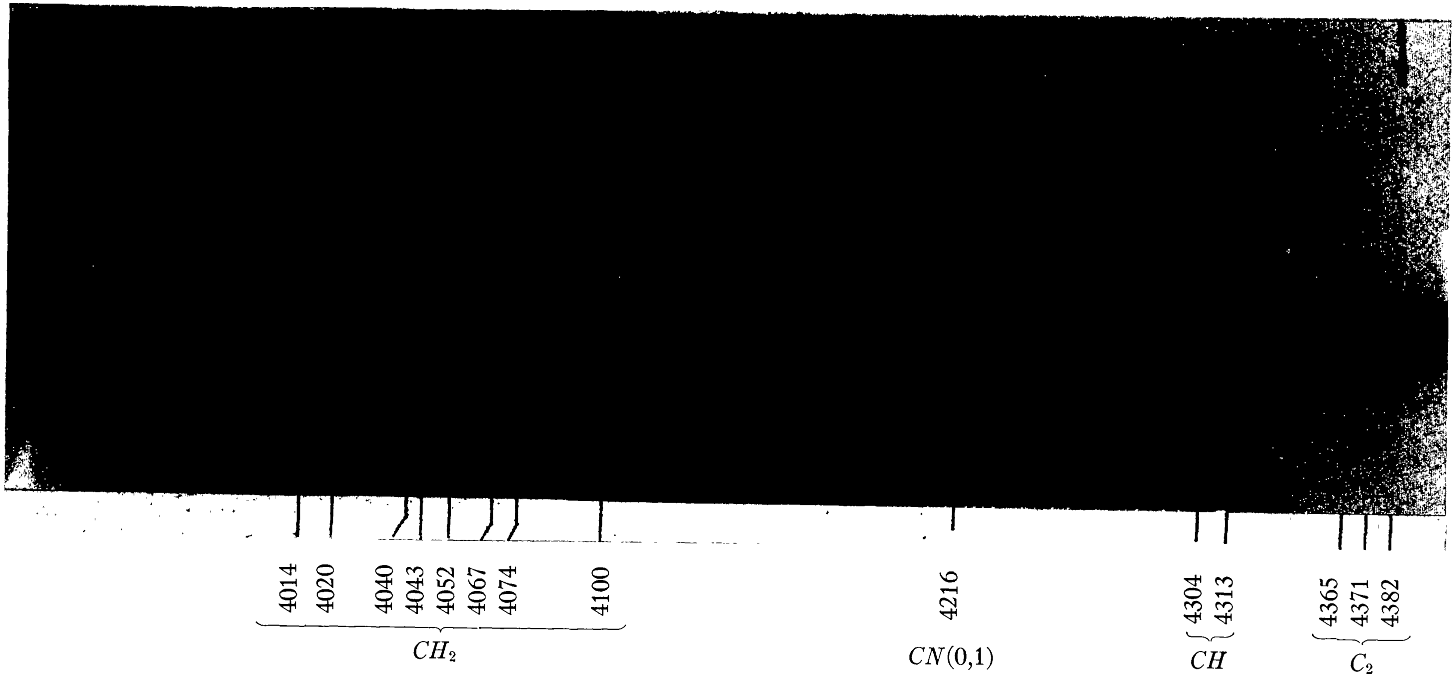

FIG. 3.—Region of the CH_2 and CH bands

λ 4050 group in different comets will reveal differences which cannot be accounted for, except by assuming the presence of two emitting molecules. But, as far as we know, the comparisons made thus far have had only a superficial character and do not warrant any convincing conclusion.

CH_2 has often been considered as the parent-molecule for CH. The intensity gradients along the lines (i.e., the intensity changes with distance from center of molecules) may thus be fruitfully compared. As appears from Figure 3, the gradients are not identical for CH_2 and CH. Both molecules are concentrated close to the nucleus, but their lines extend differently from the nucleus. The lines of CH_2 fall off in intensity less abruptly than do those of CH. It may eventually turn out that CH_2 is actually not the parent-molecule for CH but that both result directly from a common parent, such as methane, or even from two different parent-molecules.

STRUCTURE WITHIN THE SWAN BANDS OF C_2

Attention has been called in previous papers[10] to emissions appearing within the Swan bands. Within the $\Delta v = +1$ sequence of Comet 1948l, lines are observed at the following wave lengths:

Between (4, 3) and (3, 2): λ 4689.7 (1) and λ 4695.4 (2?)
Between (3, 2) and (2, 1): λ 4705.0 (1–0) and λ 4708.4 (1–0)
Between (2, 1) and (1, 0): λ 4725.9 (2) and λ 4729.5 (1)

The separations in the last two doublets are practically the same, 3.4 A (or 15.4 cm^{-1}). Within the $\Delta v = 0$ sequence, two lines have been measured at λ 5146.2 (1) and λ 5151.4 (2). Within the $\Delta v = -1$ sequence, lines are observed at λ 5562.4 (1) and 5617.7 (1).

Certain of these lines agree quite well with features observed in Comet 1940c by Bobrovnikoff[10] and in Comet 1947n by Swings and Page,[8] for example, the doublet between (3, 2) and (2, 1). Others do not. The possible meaning of these emissions has already been discussed by Swings and Page.[8] It is imperative that "synthetic profiles" be drawn for the Swan bands, assuming a fluorescence mechanism. Yet certain lines, such as λ 4725.9, appear to rise so sharply above the background of (1, 0) that they do not seem to belong to C_2. One would rather think that another molecule is responsible for such lines.

As will be seen in the next section, additional unidentified lines are observed in the visual region. Some have the same intensity gradient as the emissions falling within the Swan bands. It is likely that an as yet unidentified molecular system is present in the region from λ 4600 to the red. The importance of laboratory work on such molecules as NH^+, CN^+, and C^+ cannot be overemphasized.

THE VISUAL REGION

On account of the strong solar spectrum appearing in the region of the nucleus, Comet 1948l is not favorable to the detection or investigation of faint nuclear emissions in the visual range. This appears clearly from Figure 1. Table 3 gives the measured emissions above λ 5100. The Swan bands (0, 0), (1, 1), (0, 1), (1, 2), and (2, 3) which are observed have not been included in the table. Most wave lengths are the mean values for the three spectrograms at distances $r = 0.73$, $r = 0.78$, and $r = 1.00$.

As has been stated by various observers,[5, 6, 7, 8] the α band of ammonia, presumably due to NH_2, does not seem able to explain all the emissions observed in the visual region. In particular, certain long lines may be related to the unidentified emissions within the Swan bands rather than to NH_2. No definite identification appears convincing through a systematic examination of likely molecules. The laboratory investigations on the α band have been reviewed and discussed by Swings, McKellar, and Minkowski.[5]

Ten years ago the red system of CN was often suggested for explaining certain emissions in the visual region. Once the fluorescence excitation of the violet system of CN became proved,[22] and the low *f*-values of the vibrational transition of the red *CN* system ascertained,[28] the *CN* bands of the visual region were no longer considered. Indeed, the red *CN* bands of the visual region should not appear intensely in fluorescence. However, the recent observation[8] of intense bands in the nucleus of Comet 1947n and their probable attribution to the (2, 0) and (3, 1) transitions of the red system of *CN* have produced a

TABLE 3*

EMISSION LINES IN COMET 1948l; REGION λ > 5300

COMET 1948l		1947n	EARLIER MEASUREMENTS McD. AND MT. W.	VICTORIA MEASUREMENTS	LYON MEASUREMENTS	SUGGESTED IDENTIFICATION	NOTES
λ	Int. and Length						
5357.9............	1	51.6	55.3	....	54.4	....	
5430.7............	3 sh	27.9	....	27.7	....	NH_2	
5446.3............	2 sh	44.2	45.0	....	49.7	....	
5464.6............	0 sh	66.2	....	....	....	....	1
5650..............	1 sh	....	....	....	....	....	
5674.1............	0 sh	79.0	....	....	....	NH_2	
5694.1............	0–1 sh	....	87.1	94.6	96.3	NH_2	
5703.0............	2 sh	02.2	01.5	04.0	08.2	NH_2	
5733.5............	2 sh	32.5	31.2	31.4	....	....	
5743.0............	0–1 sh	....	39.6	41.4	42.7	NH_2	
5890.1............	4	....	....	....	....	*Na* I	2
5896.6............	2	....	....	....	....		
5978.2............	5l	74.9	77.7	76.6	77.4	NH_2?	3
5996.5............	4l	98.0	96.0	95.8	93.4	(NH_2?)	3
6018.6............	1–2 sh	17.2	19.4	20.2	19.8	NH_2	
6097.8............	2 sh	94.8	98.7	96.9	99.4	NH_2	
6111.1............	1 sh	06.6	10.3	10.0	....	NH_2	
6120.9............	1 sh	18.0	20.9	20.9	....	NH_2 plus C_2(1, 3)	4
6185.3............	1 sh	86.5	....	84.8	....	NH_2 plus C_2(0, 2)	4
6210.6............	1 sh	....	....	12.8	06.6	NH_2	
6297.7............	10 sh	97.3	98.0	00.7	98.8	NH_2	5
6318.8............	; sh	....	....	21.2	....	NH_2	
6333.1............	3–4 sh	29.5	33.2	35.2	29.4	NH_2	
6346.4............	1	45.2	45.6	45.7	45.4	NH_2	
6361.3............	1 sh	60.6	64.1	64.3	? 54	NH_2?	
6466.9............	1	....	....	74.3	....	....	

* The columns list the following: first, the mean measured wave lengths; second, the intensities and estimates of the lengths of the lines ("sh" = short; "l" = long); third, the wave lengths obtained by Swings and Page (*Ap. J.*, **108,** 526, 1948); fourth, mean values of earlier measurements made at the McDonald and Mt. Wilson observatories; fifth, measurements made at Victoria in the spectra of Comet 1941 I and 1943 I (A. McKellar, *Ap. J.*, **98,** 142, 1943, and **99,** 162, 1944); and sixth, mean values obtained by J. Dufay for Comets 1936a, 1937h, 1937f, 1942g, and 1939d (*C.R.*, **222,** 51, 1946).

NOTES TO TABLE 3

1. This is not C_2 (4, 5), since (3, 4) is absent.
2. The *Na* emission is present only for $r = 0.73$ and $r = 0.78$; it is blended in the nuclear region by a short line, which remains present at larger heliocentric distances and is probably due to NH_2.
3. The NH_2 identification is not satisfactory; the lines are too long and too strong.
4. Minor contribution of C_2.
5. Often blended with night sky or twilight [*O* I] line; strong enhancement in the nuclear region is evidence for cometary emission.

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[28] A. S. King and P. Swings, *Ap. J.*, **101,** 6, 1945. This paper concerns the (2, 0) band. The (0, 0) band at 1.05 μ is much stronger (see reference 8, n. 24).

renewed interest in the red system as a source of identification of cometary emissions. Its bands in the visual region should, like (2, 0) and (3, 1) and in contrast with the violet system, be concentrated near the nucleus. There is no reason for believing that the vibrational temperature of the red system of *CN* is as low as that of the blue system, since the excitation mechanisms are different. In fact, the identification of bands of the red system arising from $v' = 2$ and $v' = 3$ indicates that the vibrational temperature is higher for the red system than for the blue system. Hence it does not seem unreasonable to consider the possibility of transitions such as (4, 0) near λ 6200, (5, 1) near λ 6350, and (5, 0) near λ 5620. However, the identifications cannot proceed safely before synthetic profiles have been drawn for these bands. The infrared observations which were made with very low resolution revealed for the (2, 0) band a sharp maximum at λ 7906 and another shallower one near λ 7876. The red system has triple-headed bands, roughly equally spaced. The R_2 head of (2, 0) is at λ 7874, and the other two heads, R_1 and Q_1, are about 20 and 40 A to the red of R_2. With a resolution such as was used for Comet 1948l one may expect each vibrational transition to give several maxima. It is likely that some of the emissions in the visual region belong to this system. However, transitions corresponding to high vibrational levels, such as were often considered earlier, should not be retained. The fact that (3, 1) is fairly weak compared with (2, 0) indicates that the vibrational temperature of the red system, although higher than that of the blue system, is by no means very high. Such suggestions as were made by J. Dufay[6] thus appear unlikely. Pending the availability of synthetic profiles for the red *CN* bands, no tentative identification of *CN* has been entered into Table 3.