

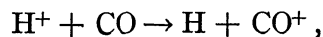
## THE SPECTRUM OF COMET HUMASON (1961e)

Comet Humason has been distant from both sun and earth. Spectroscopic observations have been difficult because of the low surface brightness and diffuse character of the nucleus. On August 1 and 2, 1962, two Palomar prime-focus slit spectra were obtained at 180 A/mm and are shown in Figure 1. The heliocentric distance, 2.6 A.U., is large compared with that at which tail spectra have previously been observed and larger than any for which slit spectra of high resolution are shown by Swings and Haser (1956). Photographs of Kearns and Rudnicki showed a distorted head and rapidly variable tail streamers, rich in blue light. Visual inspection at the prime-focus (12"/mm) and coudé (1".3/mm) showed a low-surface-brightness nucleus elongated in position angle 160°, approximately 1" × 4". The first spectrum, N 1695, was taken with the elongated nucleus along the slit, and guiding was poor. Plate N 1702 was taken in position angle 270°, nearly along the tail direction and is well guided. Although the slit seemed to cover only the head, the tail gases pervaded this inner region.

A reflection solar spectrum of the nuclear region is seen with a few sharply concentrated emission lines of C<sub>3</sub> (marked "head" in Table 1). CN is weak, C<sub>2</sub> probably absent. The persistence of C<sub>3</sub> at such large  $r$  indicates that it is particularly easily released from the parent molecule; the relative intensities of CN, C<sub>3</sub>, CH, and C<sub>2</sub> are consistent with those usually noted at large heliocentric distance.

The strength of the comet-tail bands is greater than any shown in the *Atlas of Representative Cometary Spectra*. There is no apparent brightening of the tail bands or even CN as they cross the reflection-type nucleus. The spectra show no significant change with position angle; within the 2' radial length of the slit, about  $2 \times 10^6$  km, the pure tail spectrum dominates. Two geometric effects should be noted. The surface brightness of the tail is somewhat increased by foreshortening, and the extension of the head bands decreased by the distance,  $\Delta = 1.7$  A.U. However, there is little doubt, from the measurements, of the unusual strength of the ionized tail bands. Table 1 gives a list of wavelengths (rounded off to whole angstroms). The two plates agreed to  $\pm 0.5$  Å, mean error; however, since bands are involved, the tolerance for identification is much looser. The CO<sup>+</sup> bands are very strong, and at least 35 are clearly present. The comet-tail, A<sup>2</sup>Π<sub>g</sub>-X<sup>2</sup>Σ system is represented by heads of the following sequences: (0, 0) to (7, 0); (1, 1) to (8, 1); (4, 2), (3, 2), and possibly (7, 3). The Baldet-Johnson, B<sup>2</sup>Σ-A<sup>2</sup>Π<sub>g</sub> is weak, but (2, 0), (1, 0), (0, 0), and (0, 1) may be present. N<sub>2</sub><sup>+</sup> is strong and definitely present, CO<sub>2</sub><sup>+</sup> weak. A few lines may have contributions from OH<sup>+</sup>. Swings and Page (1950) had tentatively identified a few possible bands in Comet Bester as O<sub>2</sub>, Schumann-Runge (B<sup>3</sup>Σ-X<sup>3</sup>Σ). The three possible bands, λλ 3525, 3674, and 4096, are masked by stronger features and provide no evidence for O<sub>2</sub>.

The unusual photographic forms and the predominance of the tail spectral features in Comet Humason require some explanation in terms of plasma dynamics and collisional or charge-transfer excitation. Note that the CO<sup>+</sup> bands up to (8, 1), (3, 2), and perhaps (7, 3) are present. If excitation from the lower levels by the pure resonance fluorescence mechanism occurs, there must be an appreciable population in  $v'' = 2$  and maybe in  $v'' = 3$ . Pure vibration excitation by infrared solar radiation seems implausible. Similarly, the possible existence of the Baldet-Johnson bands, a subordinate electronic transition starting from the upper level of the comet-tail bands suggests that even the electronic excitation is high. If a high-energy colliding proton strips an electron, it is possible that an appreciable excitation of vibrational levels would be produced. Biermann and Trefftz (1960) suggest that in the charge-transfer process,



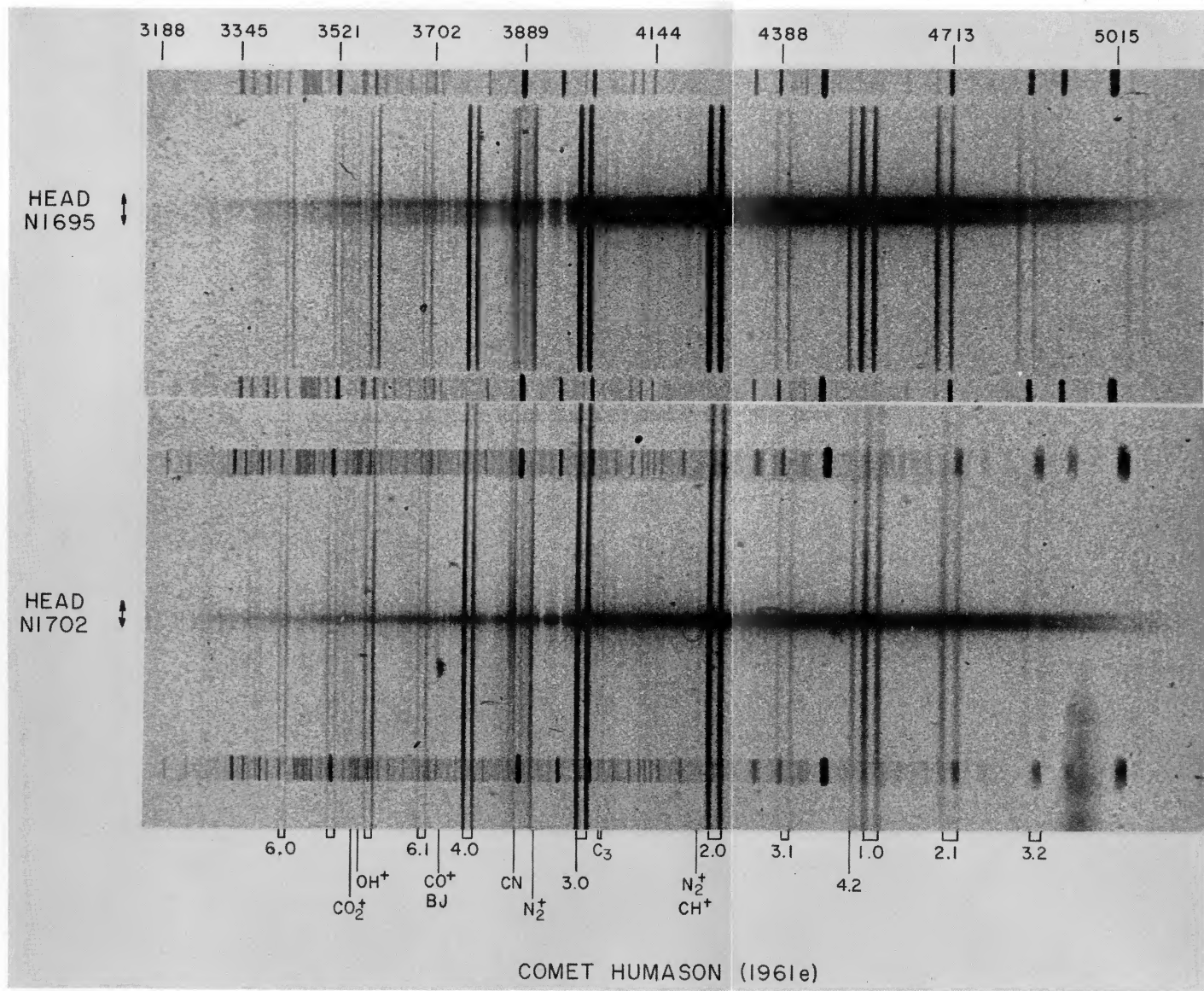


FIG. 1.—Grating spectra of Comet Humason (1961e) at  $r = 2.6$  A.U. A shorter slit was used for N 1695; N 1702, centered farther to the violet, covers 4 minutes of arc, i.e.,  $5 \times 10^5$  km. The comparisons are H, He, A, Ne. Guiding the nucleus in N 1695 was not precise. Alignment of the two spectra is imperfect because of change of focus and grating setting. The double  $\text{CO}^+$  heads are indicated by brackets. Note the concentration of  $\text{C}_3$  and the relatively higher  $\text{CN}/\text{N}_2^+$  ratio near the head.

TABLE 1\*  
WAVELENGTHS IN COMET 1961e

$\lambda$	I	Identification
3262	1	CO <sup>+</sup> R <sub>1</sub> (7, 0), CO <sub>2</sub> <sup>+</sup> (3, 1)
3273	1	CO <sup>+</sup> R <sub>2</sub> (7, 0)
3353	1	CO <sup>+</sup> R <sub>1</sub> (8, 1), NH (0, 0)
3367	1	CO <sup>+</sup> R <sub>2</sub> (8, 1), NH (0, 0)
3374	0	NH P <sub>1</sub> (3), CO <sub>2</sub> <sup>+</sup> (1, 0)
3379	0	OH <sup>+</sup> (1, 0), CO <sub>2</sub> <sup>+</sup> (1, 0)
3417	3	CO <sup>+</sup> R <sub>1</sub> (6, 0)
3431	4	CO <sup>+</sup> R <sub>2</sub> (6, 0)
3463	1	
3483	1	
3514	3	CO <sup>+</sup> R <sub>1</sub> (7, 1), CO <sub>2</sub> <sup>+</sup> (0, 0), (1, 1), CO <sup>+</sup> B.J. Q <sub>1</sub> (2, 0)
3528	2	CO <sup>+</sup> R <sub>2</sub> (7, 1), CO <sub>2</sub> <sup>+</sup> (2, 2)?
3547	1	CO <sub>2</sub> <sup>+</sup> (3, 3), (2, 2)
3562	1	N <sub>2</sub> <sup>+</sup> (2, 1), OH <sup>+</sup> (0, 0), CO <sub>2</sub> <sup>+</sup> (3, 3)
3586	4	CO <sup>+</sup> R <sub>1</sub> (5, 0), N <sub>2</sub> <sup>+</sup> (1, 0), CN P (1, 0), P (2, 1)?
3602	6	CO <sup>+</sup> R <sub>2</sub> (5, 0), OH <sup>+</sup> (0, 0)
3628	0	
3677	1	CO <sub>2</sub> <sup>+</sup> (1, 2), (0, 1)
3691	2	CO <sup>+</sup> R <sub>1</sub> (6, 1), OH <sup>+</sup> (1, 1), CO <sub>2</sub> <sup>+</sup> (1, 2)
3708	3	CO <sup>+</sup> R <sub>2</sub> (6, 1), CO <sup>+</sup> B.J. Q <sub>2</sub> (1, 0)
3728	1	CO <sup>+</sup> B.J. Q <sub>1</sub> (1, 0)
3754	1	Head?
3782	9	CO <sup>+</sup> R <sub>1</sub> (4, 0)
3799	7	CO <sup>+</sup> R <sub>2</sub> (4, 0)
3854	1	N <sub>2</sub> <sup>+</sup> (2, 2)?, CN P (2, 2)?, P (3, 3)?, CO <sub>2</sub> <sup>+</sup> (1, 3), (0, 2)
3870	2	CN P (1, 1)?, CO <sub>2</sub> <sup>+</sup> (1, 3) tail and head
3878	3	N <sub>2</sub> <sup>+</sup> (1, 1), CN R (0, 0), CN P (0, 0) tail and head
3893	1	CO <sup>+</sup> R <sub>1</sub> (5, 1), OH <sup>+</sup> (0, 1)
3912	4	CO <sup>+</sup> R <sub>2</sub> (5, 1), N <sub>2</sub> <sup>+</sup> (0, 0)
3978	1	CO <sup>+</sup> B.J. Q <sub>1</sub> (0, 0)
4000	10	CO <sup>+</sup> R <sub>1</sub> (3, 0), C <sub>3</sub>
4020	10	CO <sup>+</sup> R <sub>2</sub> (3, 0)
4038	1	C <sub>3</sub> , head
4049	2	C <sub>3</sub> , head
4072	1	C <sub>3</sub> , head
4092	0	C <sub>3</sub> , ?, head
4119	0	CO <sup>+</sup> R <sub>1</sub> (4, 1)
4133	1	CO <sup>+</sup> R <sub>2</sub> (0, 0), R <sub>2</sub> (4, 1), R <sub>1</sub> (7, 3)
4153	0	CO <sup>+</sup> R <sub>2</sub> (7, 3)
4231	1	N <sub>2</sub> <sup>+</sup> (1, 2), CH <sup>+</sup> (0, 0), CO <sup>+</sup> B.J. Q <sub>1</sub> (0, 1)
4252	10	CO <sup>+</sup> R <sub>1</sub> (2, 0), CH <sup>+</sup> (0, 0)
4273	10	CO <sup>+</sup> R <sub>2</sub> (2, 0), N <sub>2</sub> <sup>+</sup> (0, 1)
4316	1?	CH Q (0, 0), head
4329	1?	CH P (0, 0), head
4382	3	CO <sup>+</sup> R <sub>1</sub> (3, 1), C <sub>2</sub> (2, 0)?
4405	4	CO <sup>+</sup> R <sub>2</sub> (3, 1)
4503	1	
4521	4	CO <sup>+</sup> R <sub>1</sub> (4, 2)
4545	10	CO <sup>+</sup> R <sub>1</sub> (1, 0)
4568	8	CO <sup>+</sup> R <sub>2</sub> (1, 0)
4689	6	CO <sup>+</sup> R <sub>1</sub> (2, 1)
4715	6	CO <sup>+</sup> R <sub>2</sub> (2, 1), N <sub>2</sub> <sup>+</sup> (0, 2)?, C <sub>2</sub> (2, 1)?
4841	3	CO <sup>+</sup> R <sub>1</sub> (3, 2), (NH <sub>2</sub> )?
4868	2	CO <sup>+</sup> R <sub>2</sub> (3, 2)
4884	1	CO <sup>+</sup> R <sub>1</sub> (0, 0)
4914	1	
5045	3	CO <sup>+</sup> R <sub>1</sub> (1, 1)
5076	3	CO <sup>+</sup> R <sub>2</sub> (1, 1)

\* All lines are in the tail spectrum except those marked as "head," which are concentrated toward the nucleus. Measures at  $\lambda < 3415$  and  $\lambda > 4715$  are based on one plate only. No correction made for velocity (which is small). Intensities uncorrected for transparency or response-curve. All the CO<sup>+</sup> bands belong to the A<sup>2</sup>Π<sub>g</sub> - X<sup>2</sup>Σ system except for a few, weak lines of the Baldet-Johnson system, B<sup>2</sup>Σ - A<sup>2</sup>Π<sub>g</sub>.