COMET KOHOUTEK: GROUND AND AIRBORNE HIGH RESOLUTION TILTING-FILTER IR PHOTOMETRY*

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ABSTRACT

Because of Comet Kohoutek's anticipated large gas production, which seemed to offer a unique chance to reveal parent molecules, two Fabry-Perot Tilting Filter Photometers were designed with the purpose to detect and study the behaviour of CH_4 and its photolysis product H_2 The importance of these two molecules is well known and their detection would have given valuable indications about the structure of the nucleus, its thermal history and conditions of formation.

Similar to CH_4, H_2 has no dipole moment and cannot be detected by radioastronomy. The most obvious way for measuring H_2 in extended cometary comae is certainly on the basis of fluorescence from the Lyman bands around 1000Å, there are, however, vibrational quadrupole transitions within the overtone bands of the ground electronic state which give rise to emissions in the near infrared, accessible by means of ground based telescopes. Three of the stronger lines are: $\lambda = 0.8748\ \mu$; $0.8560\ \mu$ and $0.8497\ \mu$. Methane is more readily detectable in the infrared, since it has strong fundamental (1-0) infrared vibration rotation bands at $3.3\ \mu$ (ν_3). In order to measure both the CH_4 concentration and its rotational temperature, a very high resolution (~3.7Å) high throughput instrument was designed which could isolate several individual vibration-rotation lines in the ν_3 band, namely the P_2, P_3 and P_9 lines. The instrument consisting of a Fabry-Periot Tilting Filter Photometer with InSb detector interfaced with the 30 cm f/30 Dahl-Kirkham Telescope is described in detail elsewhere.(1). The observations were made in January from the NASA Convair 990 (Galileo II) at an altitude of 13 km, where atmospheric methane absorption can be minimized but not avoided. Doppler shift of cometary and atmospheric lines with respect to one another by at least a few Å caused by the orbiting velocity of the comet would be sufficient to allow for high transmission measurements. Though long integration time measurements with Lock-In-Amplifier technique have been carried out, no signals from the CH_4-rotational lines of the comet coma could be detected. Using the planet Venus as a calibration source for the photon flux and as a result of delicate laboratory measnrements an upper limit of

$$Q_{CH_4} \leqslant 5 \quad 10^{28} \text{ molecules/sec sr}$$

could be derived. This value is several orders of magnitude less than the original predictions for Kohoutek during close approach. Therefore, one could conclude that volatile components like CH_4 boiled off the comet well before perihelion, at large (~4 AU) distances from the sun and were responsible for the high brightness of the comet at that time. Such a fractionation is only possible if the nucleus was composed of relatively loose, porous ice, rather than compact ice. This hypothesis was strongly supported by the second experiment for search of H_2 in the near infrared at the 182 cm telescope of Asiago. Also in this case a Fabry-Perot tilting filter photometer was designed to match with the f/9 optics of the telescope. The instrument (2) consists in a high resolution (~0.7Å) tilting filter system with photon counting technique which allows phase-sensitive background subtraction. On the basis of the best

*The full text of this paper has appeared in ICARUS 23, No. 4 (1974).

data achieved between January 10 and 15 the occurrence of H_2-lines with an intensity larger than 2% of the continuum could be excluded, viz. the flux averaged over the field of view was less than 4.10^5 photons/cm^2 sec sr Å. Since the pre- and post-perihelion measurements were not affected by molecular fluorescence, they represent only the light scattering flux from dust particles. The data display that the comet's dust coma was definitely brighter during approach than during recession from the sun. However, the quantity of more fundamental interest is the difference in dust production rates, and a derivation of the mass-production rate of dust could be derived. The study shows that both the dust and gas production rate differ greatly in the pre-perihelion period as compared to the post-perihelion period, as conjectured previously for "virgin" comets. (Dust production rate/gas production rate: pre-perihelion 0.1, post-perihelion 1). The pronounced asymmetry in the production rates strongly suggests that fractionation and dust entrainment effects have to be considered in brightness predictions of young comets, the nucleus of which will generally consist of a multi-component mixture of parent molecules.

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[1] Roche, A., Cosmovici, C. B., Drapatz, S., Michel, K. W., and Wells, W. C., Icarus (in press) 1975

[2] Barbieri, C., Cosmovici, C. B., Michel, K. W., Nishimura, T., and Roche, A., Icarus (in press) 1975

DISCUSSION

H. Keller: $\dot{M}_D/M_G$ should be the same for pre- and post-perihelion, due to infrared and H-gas production rates.

C. Cosmovici: The gas production rates are not our measurements; we just took the gas production from other people's measurements.

W. F. Huebner: I wish to point out that a group from Los Alamos also made aircraft observations of Comet Kohoutek on six different occasions before and after perihelion, starting in mid-December. The aircraft used was a Boeing 707 type jet. The aircraft was flown at altitudes up to 13.5 km. The infrared range covered was from about 1 to 14 microns. Our upper limit for the CH_4 molecule production rate is somewhat higher than the one reported here. The work has not been published since the upper limit is so high. A number of visual instruments were also on board, including a spectrograph that covered part of the near IR, and a polarization experiment. Guiding was accomplished with an on-board computer electronically connected to image intensifier cameras.

D. D. Meisel: Measurements with our Fabry-Perot on the 1.1 micron J = 0 lines agree that CH_4 appears to be absent.

H. Keller: H_2 as a dissociation product of CH_4 should lead to an extended source for H-Lyα, which should be detectable in the intensity distribution.

M. Mumma: I would like to comment on the general problem of detecting molecular emissions in the infrared in comets. One of the serious problems is that the molecular line profiles that you expect to see are only on the order of 50 MHz wide. What this means, essentially, is that if you have an instrument such as an iris interferometer that has a resolution of one wave number, you are trying to look for a molecular line that has a half-width of, say, a milli-wave-number, so the intensity dilution factor is more than 1000 to 1. The problem is even worse if you have a broad band filter. If you go to a tilting filter, where you have a resolution perhaps on the order of 10^{-2} wave numbers at 3 to 5 microns, then the dilution factor is only 10 to 1. In principle, the new technique of heterodyne spectroscopy gives you the ability to measure these IR emissions at resolutions that are 10 to 15 times narrower than the line widths.

M. K. Wallis: What is the significance of your upper limit on CH_4? It is larger than the production rates of H and C given earlier by Keller, by a factor of 2 or 3. The CH_4 limit therefore seems interesting.

DISCUSSION (Continued)

G. S. D. Babu: In my observations of Comet Kohoutek from 7 to 15 December 1973, I found a large deviation of the flux in C_2 ($\Delta V = 0$) on 11.013 Dec., 1973 (UT) as compared to the other dates. It seems to agree with the IR magnitude deviation on the same date obtained by yourself. Perhaps we can relate it to some process that took place in the comet.

C. Cosmovici: I think that is a very interesting comparison, since the two observations have been made, one in India and one in Italy, in two different regions of the spectrum, so that experimental errors can be excluded. I propose also to check photographs taken between the 10th and the 12th of December, in order to try to obtain some conclusions from this peculiarity.

L. Biermann: Before closing this session I would like to draw attention to the work of Rank, Towns, and associates, on their attempt to measure CO emission at 4.7 microns in Comet Kohoutek. Though bad weather and other transient difficulties prevented real observations being made before the comet had reached a solar distance of 1-1/2 A.U., and thus only an upper limit could be established, there seems to be every reason to hope for positive results for future medium-bright comets, provided the relative production rate of CO is of the order of 10% or more of what would be expected on the basis of recent work.

https://doi.org/10.1017/S025292110050102X Published online by Cambridge University Press