1 up

CR114738
AVAILABLE TO THE PUBLIC

AIRBORNE OBSERVATIONS OF METHANE IN COMET KOHOUTEK

By A. E. Roche and W. C. Wells

February 1974

(NASA-CR-114738) AIRBORNE OBSERVATIONS OF METHANE IN COMET KOHOUTEK Final Report (Lockheed Missiles and Space Co.) 11 p HC $4.00 CSCL 03B N74-18497 Unclas G3/30 31777

Prepared under Contract NAS2-7991 by
LOCKHEED PALO ALTO RESEARCH LABORATORY
Palo Alto, California

for

AMES RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LMSC/D358455

FINAL REPORT

Contract NAS2-7991

Airborne Observations of Methane in Comet Kohoutek

A. E. Roche

A. M. Title

W. C. Wells

Lockheed Palo Alto Research Laboratory
3251 Hanover Street
Palo Alto, California 94304

L. Biermann

S. W. Drapatz

K. W. Michel

Max-Planck-Institut-für Physik und Astrophysik
Institut für Extraterrestrische Physik
8046 Garching bei München, Germany

C. B. Cosmovici

Department of Space Physics
University of Lecce, Lecce, Italy

22 February 1974

Preparation of the Experiment

Contractual agreements were completed in late November 1973 and problems relating to the installation of the infrared tilting-filter photometer on board the NASA Convair 990 aircraft were pursued immediately.

A mounting structure was designed and constructed to produce adequate mechanical interface between the Lockheed photometer with the associated electronics and the aircraft. During December, Lockheed personnel, Drs. A.E. Roche and W.C. Wells, spent some time at NASA Ames Research Center where the Lockheed Infrared Tilting-Filter Photometer was installed in the aircraft. Figure 1 shows diagramatically the photometer which was mounted on the back of the University of Arizona Dahl-Kirkham 12" f-30 telescope. The telescope viewed horizontally by way of a gyrostabilized heliostat through a 14° quartz window of the Convair 990. The photometer-telescope-heliostat assembly could be raised and lowered en masse to afford a nominal elevation angle for viewing in the 0-25° range.

The main features of the flight qualified Lockheed Infrared Tilting-Filter Photometer system are enumerated below.

- 3 switchable blocking filters, in conjunction with a unique solid-spaced Fabry-Perot interference filter which was tilt-scanned, allowed us to scan the low and middle portions of the P branch and the Q branch of the 3.4 micron methane (ν_3) band.
- A resolution of $\sim$ 3.7 Å (corresponding to a resolving power of $\sim 10^4$ at 3.4 μm) was achieved, with the option of going to a resolution of 2 Å (see Figure 2) where desired. This high resolving power is essentially state-of-the-art in flight qualified infrared instrumentation.
- The Fabry-Perot filter could be continuously and automatically tilted to scan a 60 Å region at each of the blocking filter wavelengths. A pulse was generated by the tilt device at a fixed

point during each scan and displayed along with the signal to monitor the filter/wavelength position. Alternatively an external vernier allowed for manual setting of the filter angle at any desired position where long integration times on a given emission line were desired.

- A very high noise equivalent power was achieved by using a liquid nitrogen cooled InSb photovoltaic detector having a 0.5 mm diameter active element and a cooled narrow band ($\Delta\lambda \simeq 0.2$ microns) filter mounted in the Dewar. A vibrating-reed focal plane chopper having $\nu \simeq 150$ Hz allowed for phase sensitive detection and integration times up to 300 secs, corresponding to equivalent noise bandwidth in the millihertz range.

- By means of a 45° dichroic mirror (kindly suggested by Dr. Frank Low) which reflected 95% of the infrared radiation while passing 90% of the visible light, we were able to visually acquire the comet using a line of sight eyepiece on the main telescope. This technique proved invaluable in view of the unexpected low visual intensity of the comet.

- Realtime monitoring of the infrared signal and filter position was afforded by a continuous pen chart record of the synchronous (dc) output of our phase sensitive detector and a time event marker referenced to the filter position indicator. In addition these signals and all unprocessed outputs were recorded on magnetic tape.

All installations were completed and the system was functioning perfectly prior to flight 1 on December 30, 1973.

Observations

A total of 10 flights were made under this contract. For the first few flights, we flew with the two Lockheed investigators and Dr. K. Wolfgang Michel from the Max-Planck-Institut and Dr. C.B. Cosmovici from the University of Lecce. After flight 4, we established the instrument could be operated by only two experimenters. During the balance of the flight program, including the ASSESS week, the experiment was operated by the two Lockheed investigators. During flight 1, shortly after perihelion, the comet was not observed visually from the aircraft. Flights 2-5 resulted in visual acquisition of the comet with the telescope phase calibration runs on Venus, and the determination of an upper limit for methane radiance from the comet. Subsequent flights were used to make measurements of atmospheric methane absorption using the sun as a background source. These measurements were carried out as a function of altitude and solar elevation angle. Throughout these flights (2-10) all systems worked perfectly and in particular no optical calibration problems were encountered as a result of vibration.

During the last flight we changed the filter and detector on the photometer to observe HeI 10830 Å twilight emission.

Data Processing

All the data from these flights will be processed. For analysis of the atmospheric methane data the navigator's log book will be examined to determine the altitude and position of the aircraft as a function of U.T. We will also make use of the tropopause temperature information taken in flight by Dr. Peter Kuhn of NOAA. These data will be reduced to give absorption line profiles as a function of solar elevation angle and altitude.

Data Analysis

This contract did not provide for an extensive data analysis effort. It is planned that this will be carried out under other programs.

Preliminary quick look analysis of the Comet Kohoutek data resulted in establishing an upper limit to the comet's fluorescence radiation in methane lines around 3.3 μ. The upper limit established was 3×10^{-10} w/cm^2-sr-line and corresponds to an upper limit for methane production from the comet of about 5×10^{29} molecules/sec at a heliocentric distance of about 0.4 A.U. This result is significantly lower than the predictions of currently accepted cometary models and thus has great import.

Figure 3 shows some unnormalized line profiles of the P2 line taken with the 4 Å filter. The bottom three traces show laboratory absorption spectra taken as a function of pressure. The top trace shows the earth's absorption taken against the sun. Spectra like these will be analyzed as a function of altitude and solar elevation angle to yield methane column densities and ultimately methane altitude profiles.

Publications

A paper describing the cometary methane observations will be submitted to Icarus and presented at the Annual Meeting of the [German] Astronomical Society in Munich, Germany (March 8-10, 1974). The atmospheric methane measurements will be presented at the San Francisco A.G.U. meeting and in a paper to be submitted to the Journal of Geophysical Research.

Acknowledgements

Constructing, testing and flying a new and unique experiment in less than two months could not have been possible without the able assistance of many people, too many unfortunately to enumerate here. The fact that the experiment operated successfully on the first flight is as much a testimonial to the able support we received as it is to the inherent ruggedness of our tilting-filter photometer.

In particular we would like to thank Drs. Frank Low and Hugh Johnson for their many helpful comments. Mr. J. Hall was most helpful in carrying out filter calibrations for us at Kitt Peak National Observatory. Dr. John Evans and other LMSC personnel were most helpful in many ways during the final hectic days of preparation. Also working many long days was the infatigable ground support crew at NASA-ARC who performed the impossible task of readying Gallileo II for flight in less than a month. In particular we are indebted to Mr. L. Haughney and his assistants who ably managed this whole operation. Finally, this program would not have been possible without the able guidance of Drs. Billy McCormac and Martin Walt who, at the last moment, were able to procure fixed asset funds from LMSC upper management for the construction of the photometer.

Figure Captions

Fig. 1: Tilting Filter Photometer Diagram.

Fig. 2: Typical transmission profiles for the 4 and 2 Å solid-spaced Fabry-Perot filters.

Fig. 3: Typical tilting filter absorption spectra for atmospheric methane (a) and laboratory absorption cell measurements (b-d) as a function of pressure. Tic marks at the top indicate the extreme angular tilt position of the filter.

INFRARED TILTING FILTER PHOTOMETER
INTERFACED WITH TELESCOPE

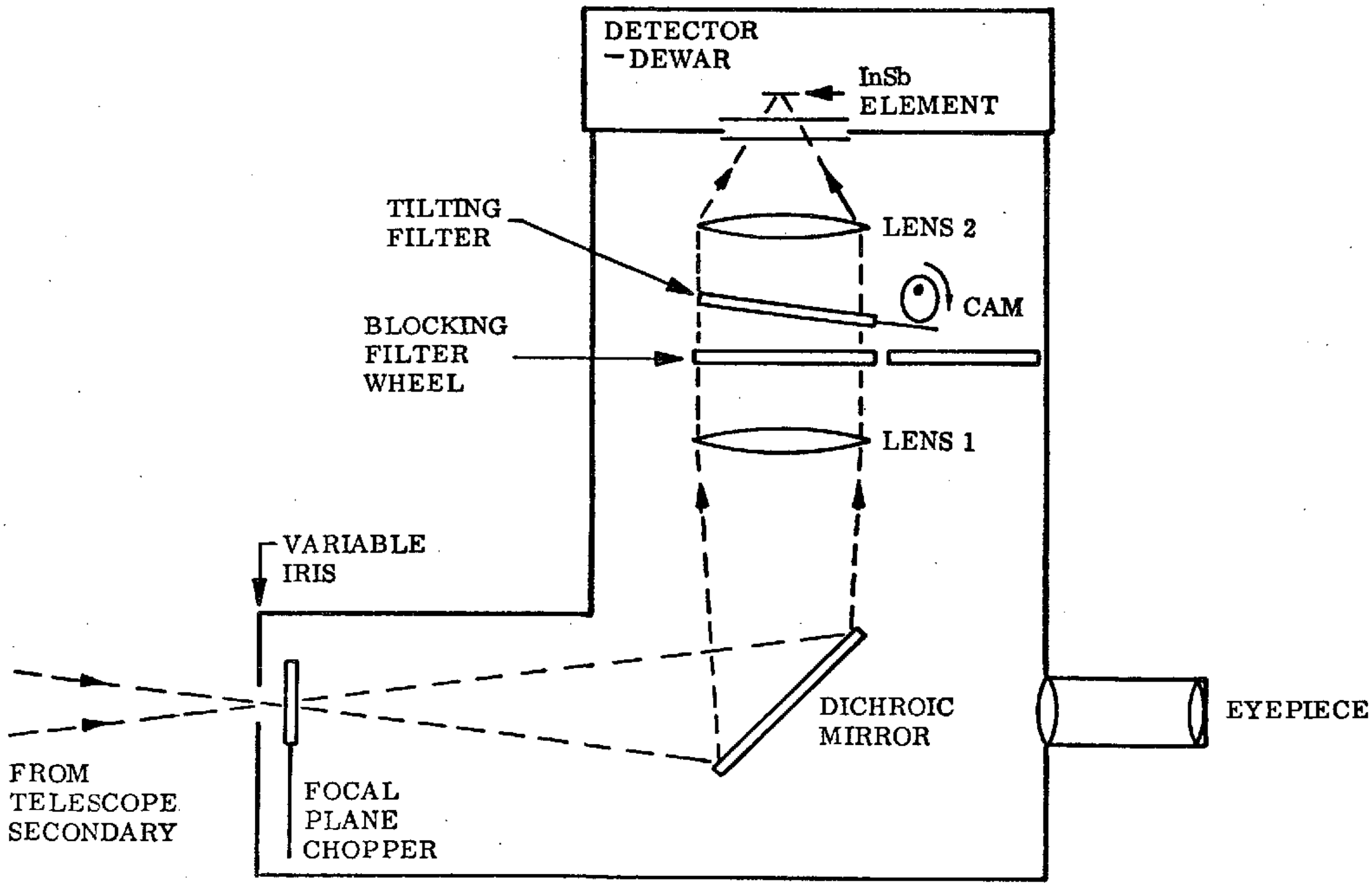
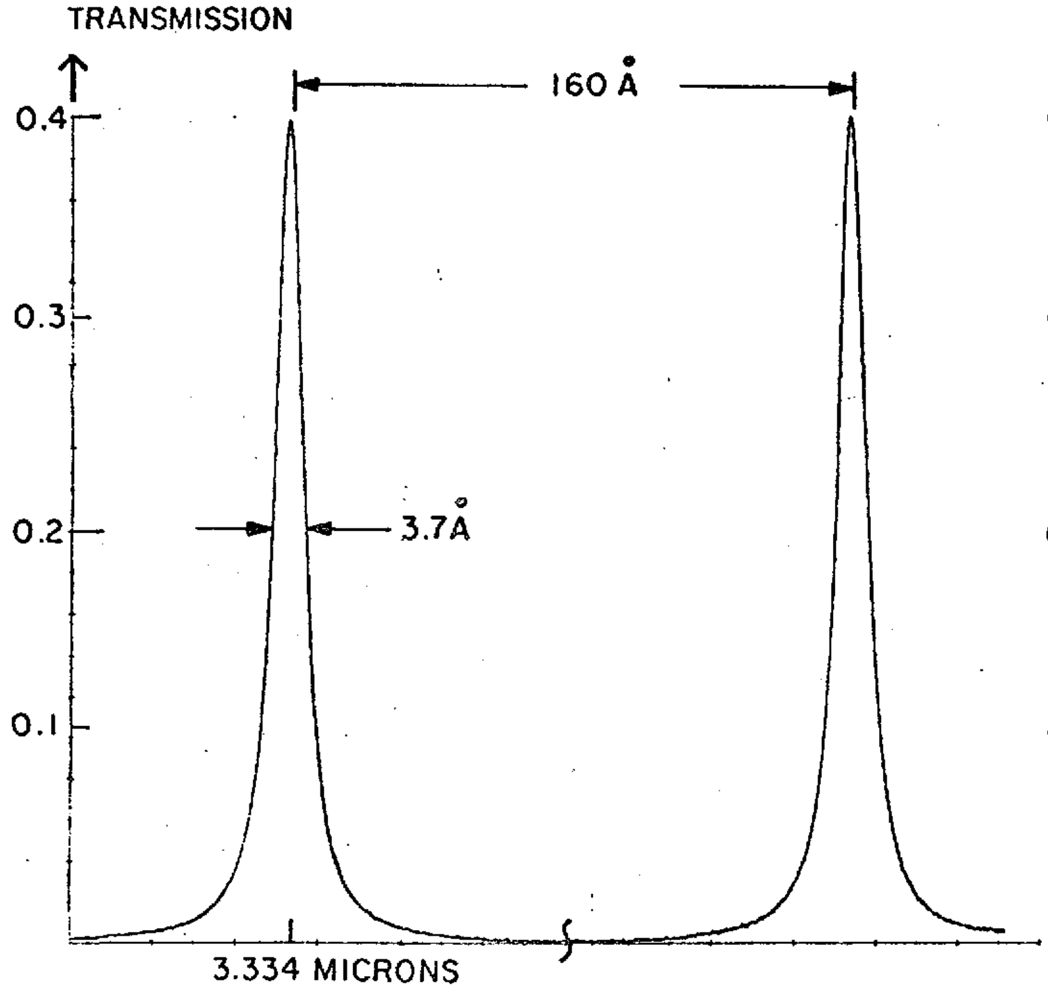
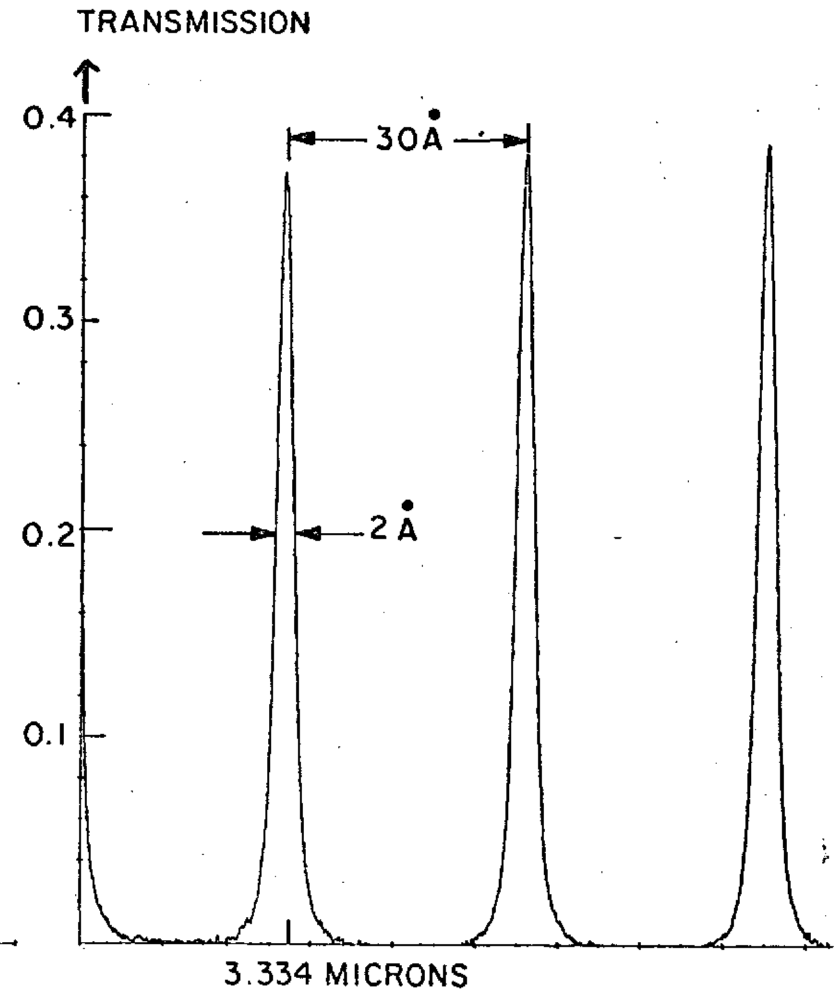


FIGURE 1



Measured transmission band profiles of 3.3 micron (CH_4) solid-spaced Fabry-Perot filter. Finesse = 43, Resolving power $\sim 10^4$.



Measured transmission band profiles of 3.3 micron (CH_4) solid spaced Fabry-Perot filter.

FIGURE 2

TILTING FILTER ABSORPTION
SPECTRA OF CH_4 LINES

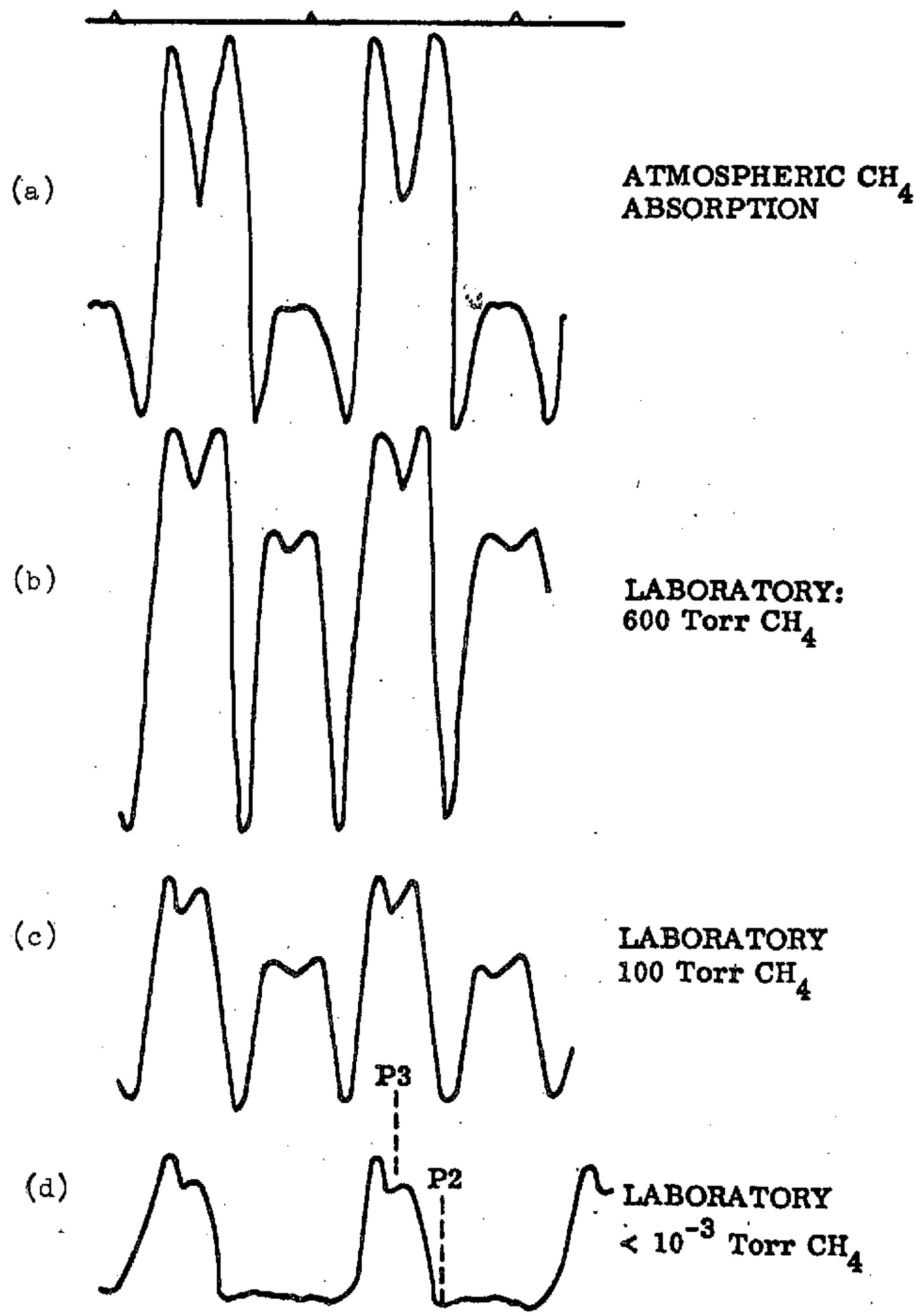


FIGURE 3