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Final Report

NASA Grant NGR 03-002-392

Infrared Spectroscopy of Comet Kohoutek

Submitted May 15, 1975

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(NASA-CR-142809) INFRARED SPECTROSCOPY OF COMET KOHOUTEK Final Report (Arizona Univ., Tucson.) 14 p HC $3.25 CSCL 03A

N75-24597

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Summary

This grant was obtained to make infrared spectral observations of Comet Kohoutek during its apparition in Dec. 1973-Jan 1974. Unfortunately, due to the faintness of the comet, a factor of one hundred or so below the predictions, and the inclement weather in Tucson during the time of its brightest intensity, we were not able to obtain any spectra of the comet. A list of attempted observations is given in Table I.

We therefore asked in a letter to Dr. Steve Maran (see Appendix 1) whether we could use the money that was not spent on the comet work to do laboratory reflection studies of ices that could be useful in future cometary work. This request was granted in a letter of April 8, 1974 by Genevieve Wiseman (Appendix 2). All the laboratory work on the ices has been completed, but the computer reduction and analysis is not quite complete. However, since the final report on this grant is now overdue, we are presenting the data that was obtained. We are planning two publications from this work:

Near infrared spectra and analysis of H_2S frost as a function of temperature - John R. Ferraro and Uwe Fink

Infrared laboratory spectra of frosts for comparison with planetary observations - Uwe Fink, J. R. Ferraro, H. P. Larson, N. Gautier, and W. Wisniewski.

The results of our ice analysis that have been reduced are described further below, and the spectra are shown in the Appendix.

I. Comet Kohoutek observations

The observations attempted for Comet Kohoutek are listed in Table I. Unfortunately before perihelion we simply could not track the comet into daytime. During our effort at the 90", Dec 15-18, we picked the comet up every morning but could not track it more than half an hour into dawn. With our broad bandpass of about 100-500 cps, which is necessary for our interferometer, we could not detect a signal.

We were hoping that during our run from Dec 21 to Dec 24 at the 60" the comet's brightness would improve sufficiently that we could track it. The morning of Dec. 22 was especially quite clear with good seeing and we could pick up 5th magnitude stars routinely during the daytime, but we could not find the comet. A search for the comet by means of its signal was seriously hampered by a large signal from scattered sunlight, since by now the comet was quite close to the sun.

Conditions after perihelion should have been much more favorable with the comet somewhat brighter, higher in the sky and farther from the sun. For this reason we scheduled two interferometers on two telescopes: the Block interferometer at the Steward Observatory 90" telescope and the Idealab interferometer at the LPL 61" telescope. Unfortunately three successive winter storms moved in, and it was cloudy during all of our scheduled telescope time to about Jan 10th.

We feel that if the weather had been favorable after perihelion we would have stood a good chance of getting some data. Since the intensity of the comet was far below predictions, our observing window, during which we felt we could get reasonable data, was narrowed down to a short time period around perihelion and conditions were simply not in our favor, even though we had spent all of December and a good part of January solely on the comet.

II. Laboratory frost observations

The frosts that were studied in the laboratory were: H_2O, CO_2, NH_3, H_2S, CH_4, NH_4HS and ammonia polysulfide. Spectra of all these frosts except the last two have been reduced, and are shown in the figures. All the spectra show remarkable changes with the temperatures that can be seen in the figures. It is quite clear from these data that if frost spectra are required for comparison with observed cometary or planetary absorption, the temperature of the frost must be matched. Conversely if these frosts are detected, their temperature dependence can be used to determine the ice temperature of the frost responsible for the absorptions. Since the frost data described above are not available from the literature, we plan to publish these shortly, as mentioned in the Summary, as soon as the last two frosts are reduced.

Hydrogen sulfide frost changed its appearance so drastically between 113^{o} K and 125^{o} K that a special effort for its analysis was undertaken. This was carried out mainly by Dr. John R.Ferraro, a distinguished visiting scientist from the Argonne National Laboratory. We found that the change in the ice's spectrum is due to a phase change from a low temperature tetragonal unit cube to a higher temperature face centered cubic structure.

Table II shows the selection rules for the internal and external modes of the low temperature phase (phase III). Table III summarizes the selection rules and compares them with experimental results. With the assignment of the combination bands made in this study, the first complete vibrational assignment that has been made for phase III of H_2S including the near, mid, and far infrared regions, has become possible.

Table I

Summary Comet Kohoutek Observations -- Interferometry

MST Date	Interferometer & Telescope used[a]	Predicted Total Magnitude[b]	Predicted Nuclear Magnitude[c]	Comments
1973 Dec. 15	Idealab IF 90"	2.5	6.5	6^{15} dawn, 6^{30} found comet and start telescope drive (7° above horizon), 7^{00} lost comet in sky, 7^{20} sunrise. Did not see a signal from the interferometer.
1973 Dec. 16	"	2.2	6.2	
1973 Dec. 17	"	1.9	5.9	
1973 Dec. 18	"	1.6	5.6	
1973 Dec. 21	Idealab IF 61"	0.5	4.5	could not find comet in daytime sky, either by eye or by signal; could find 5th magnitude stars routinely
1973 Dec. 22				
1973 Dec. 24	Block IF 61"	-1.0	3.0	cloudy
1974 Jan. 1	Idealab IF 61"	-1.7	2.3	top of Mtn. was in clouds.
	Block IF 90"	-1.2	2.8	high winds, could not open telescope
1974 Jan. 2	Idealab IF 61"	-1.2	2.8	cloudy
	Block IF 90"			"
1974 Jan. 3	Idealab IF 61"	-0.7	3.3	see note d
	Block IF 61"			top of Mtn. was in clouds
1974 Jan. 4	Idealab IF 61"	-0.3	3.7	cloudy
	Block IF 90"			cloudy
1974 Jan. 5	Idealab IF 61"	0.1	4.6	cloudy
	Block IF 90"			cloudy

Notes:

(a) 61" -- 61" LPL telescope in the Catalina Mtns., Tucson, Ariz.
90" -- 90" Steward Observatory telescope on Kitt Peak, Ariz.

(b) Total predicted magnitude taken from ephemeris by D. K. Yeomans. His weaker estimates, which seemed to be close but still a little too bright, were used.

(c) Nuclear magnitude estimated by subtracting 4 magnitudes from table.

(d) Jan. 3 partially cloudy till noon. Then telescope could not be opened because of dripping water from dome. From about 3^{00} it was clear but night assistant was scheduled to work only till 4 o'clock and refused to work thereafter. Saw comet with the naked eye after sunset and using binoculars by comparison with nearby β Cap estimated nuclear magnitude to be about +4.0.

Table II. Selection rules for solid H_2S (Phase III) using the correlation method.

Internal Modes

C_{2v} (Point Symmetry)			C_1 (Site Symmetry)	C_{4h} (Factor Group)
				3Ag (ν_1,ν_2,ν_3)
8	ν_1,ν_3	A_1		3Bg (ν_1,ν_2,ν_3)
		A_2		3Eg (ν_1,ν_2,ν_3)
		B_1	24A	3Au (ν_1,ν_2,ν_3)
8	ν_2	B_2		3Bu (ν_1,ν_2,ν_3)
				3Eu (ν_1,ν_2,ν_3)

External Modes

Degs. of Freedom (T,R)	C_1	C_{4h}	Modes T,R
		Ag	3.3
		Bg	3,3
(24,24)	$A(T_x,T_y,T_z)$	Eg	3,3
	(R_x,R_y,R_z)	$Au(T_z)$	3,3
		Bu	3,3
		$Eu(T_x,T_y)$	3,3

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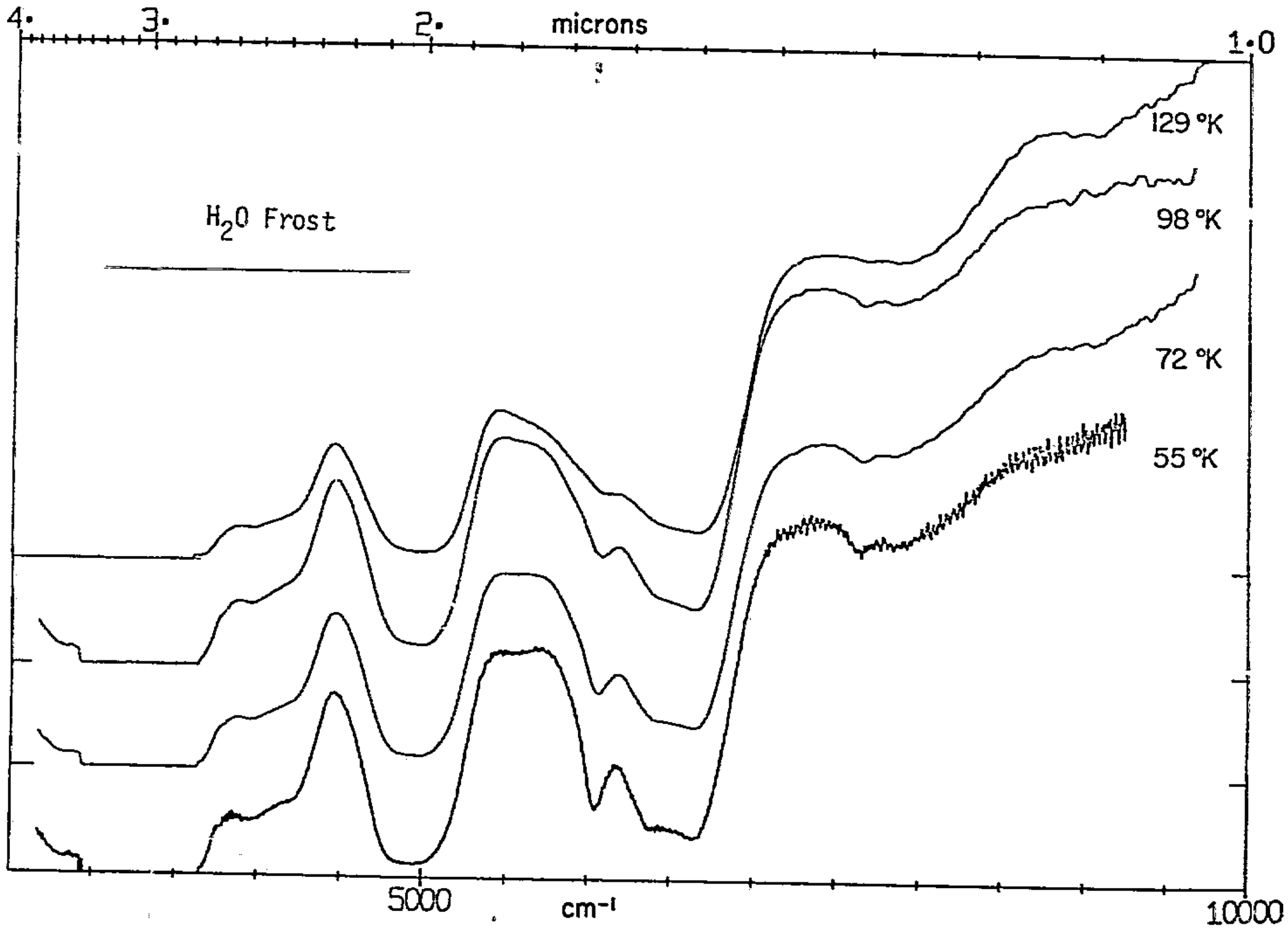
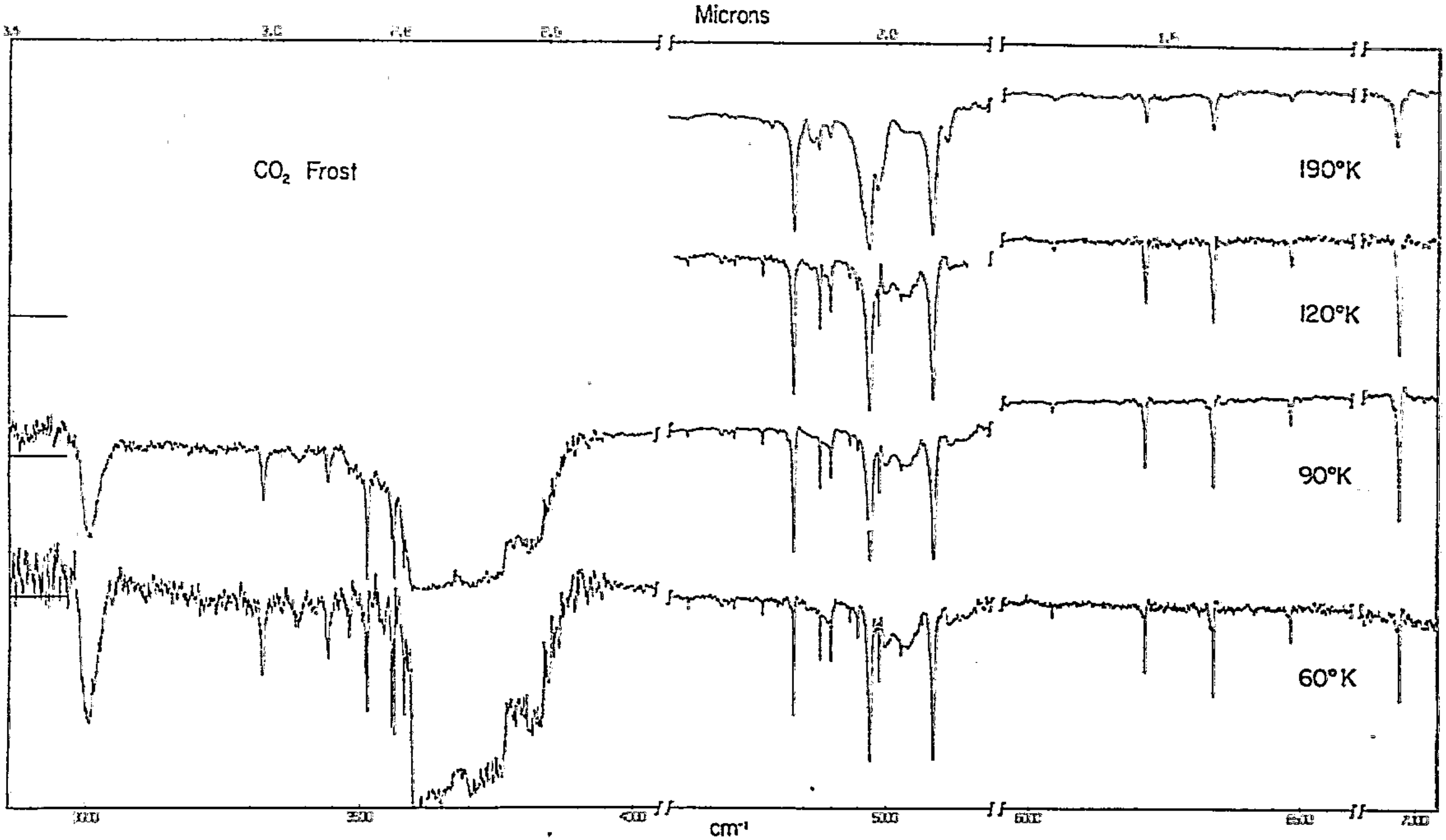
Table III. Comparison of predicted and experimental results for solid H_2S (Phase III).

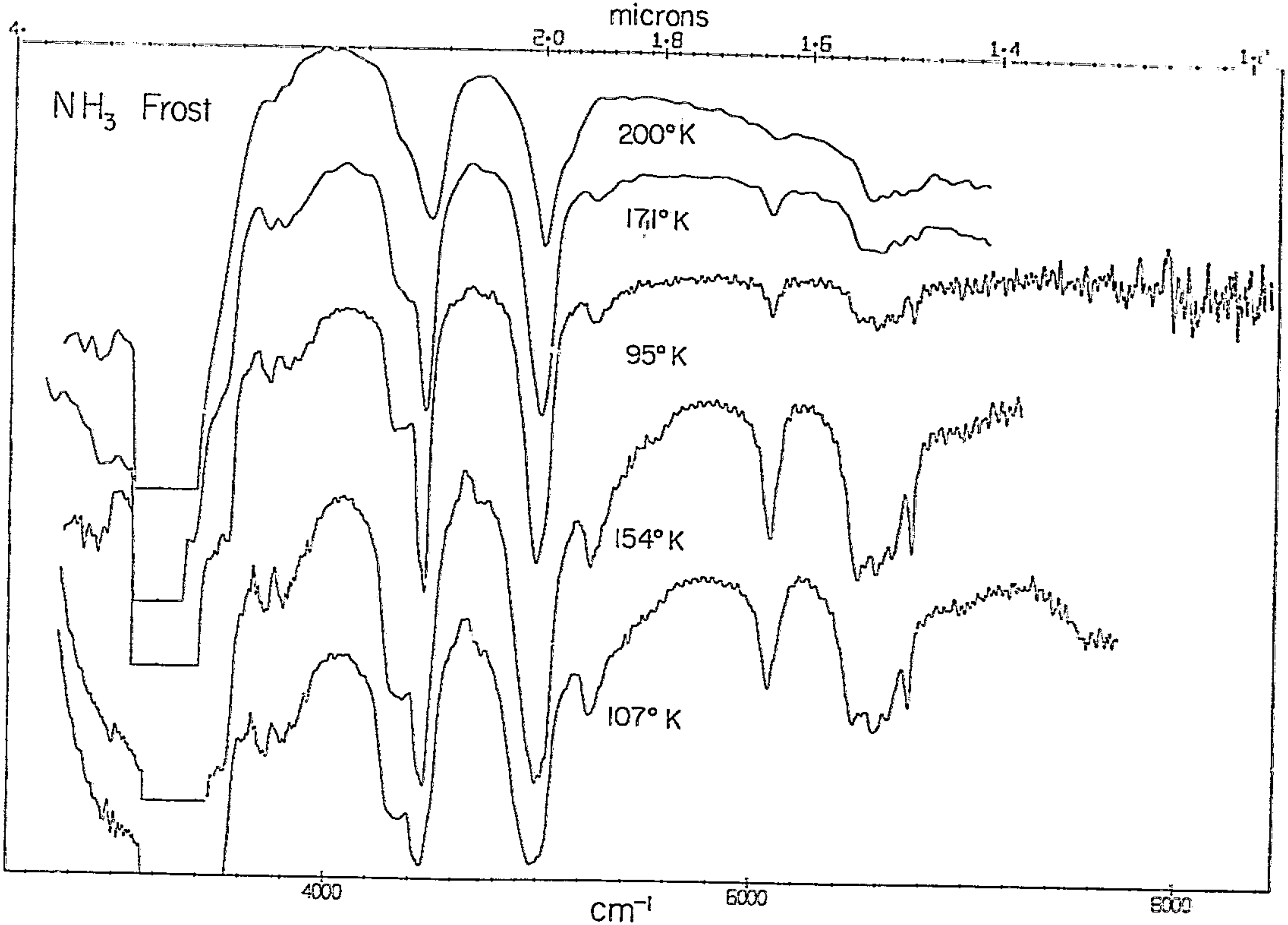
Predicted Results Based on a C_{4h} Factor Group	Internal Fundamental Modes			External Modes	
	ν_1	ν_2	ν_3	T_1	R
IR	2	2	2	4	6
R	3	3	3	9	9
Experimental Results	ν_1, ν_2		ν_3	T	R
IR	3		2	4	5
R	6		2	5	6

Abbreviations: IR = infrared; R = Raman, T = translation; R = rotation.

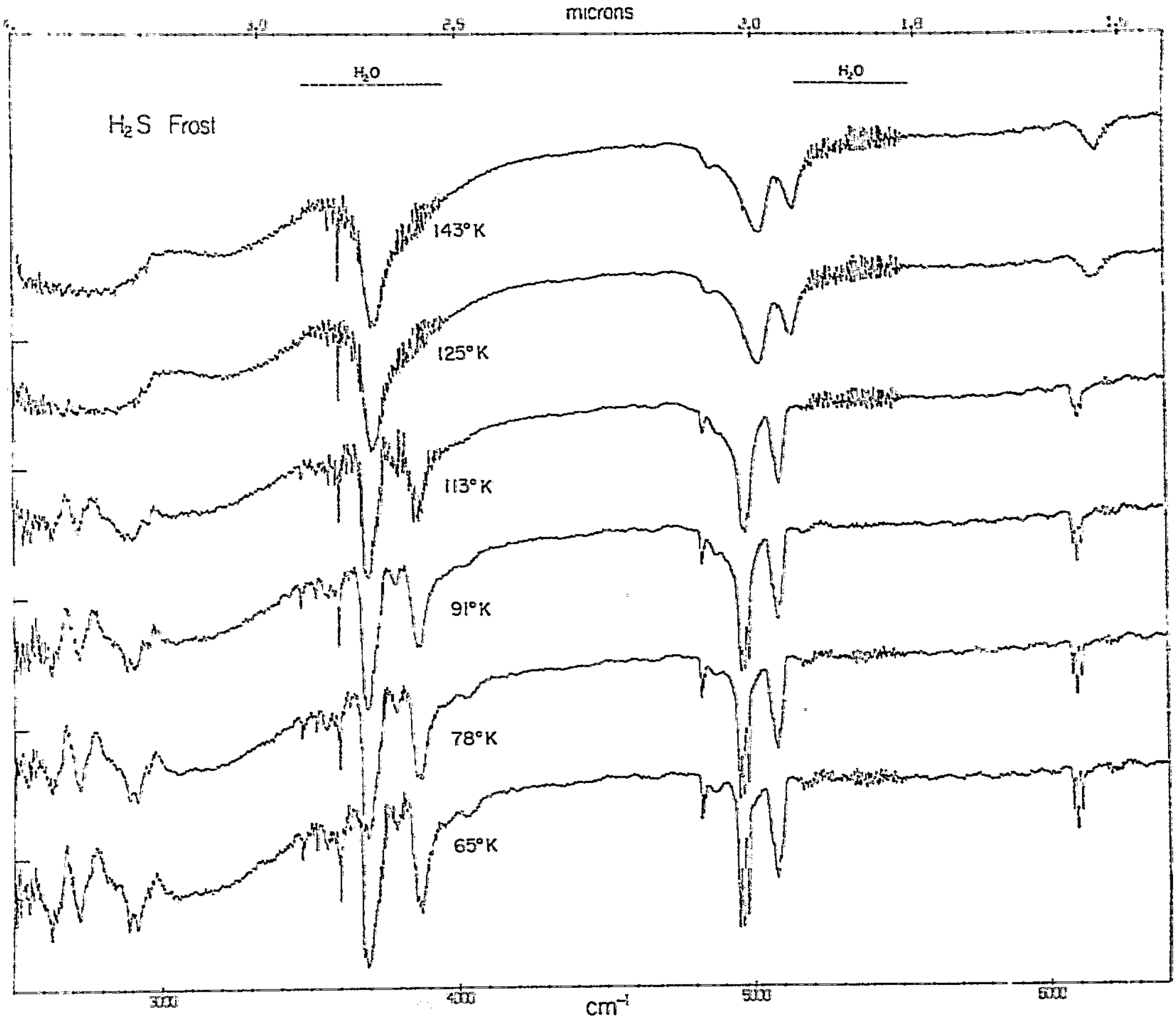


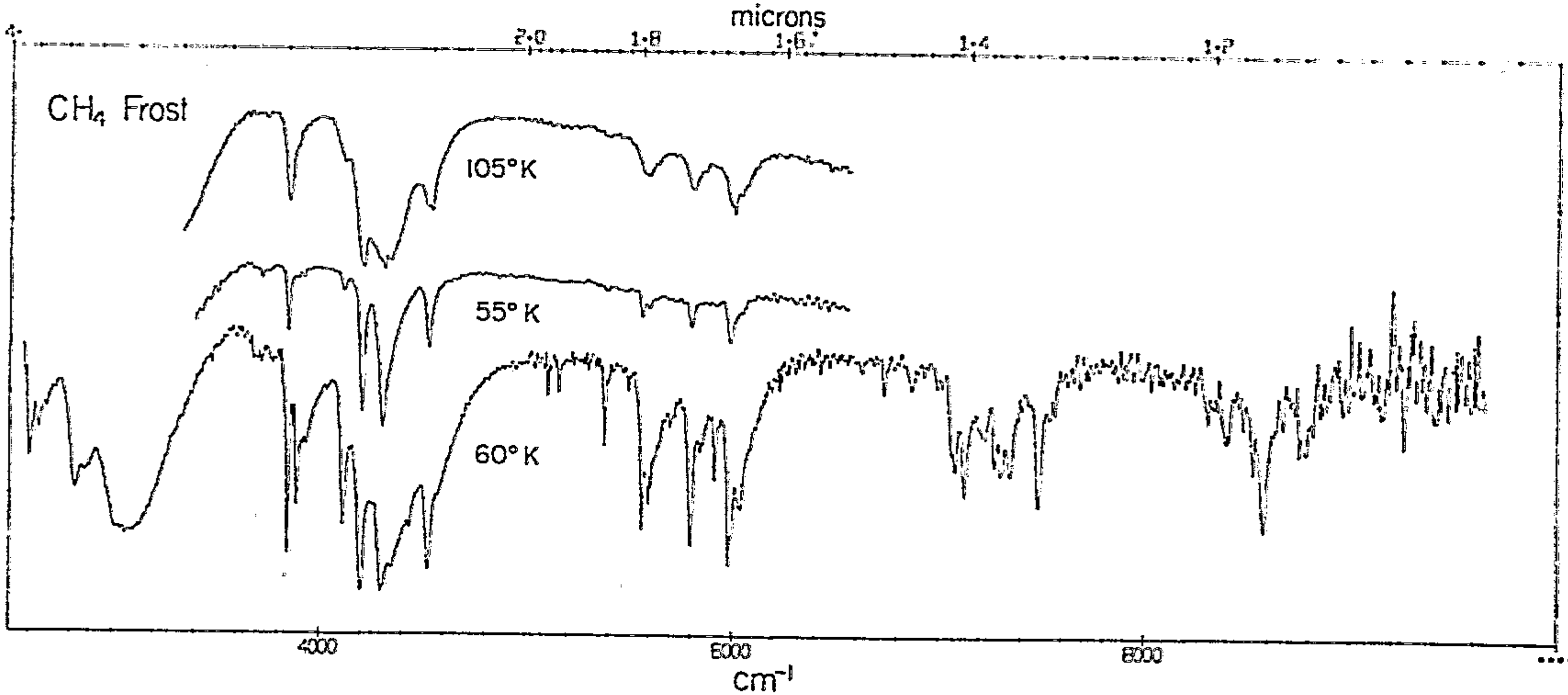
4.
3.
2.
microns
1.0
H_2O Frost
129 °K
98 °K
72 °K
55 °K
5000
cm⁻¹
10000


Microns
CO2 Frost
190°K
120°K
90°K
60°K
cm⁻¹



microns
2·0
1·8
1·6
1·4
NH3 Frost
200° K
171° K
95° K
154° K
107° K
4000
6000
8000
cm⁻¹


microns
3.0
2.5
2.0
1.8
H₂O
H₂O
H₂S Frost
143°K
125°K
113°K
91°K
78°K
65°K
3000
4000
5000
6000
cm⁻¹


microns
2.0
1.8
1.6
1.4
1.2
CH4 Frost
105° K
55° K
60° K
4000
6000
8000
cm-1

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

LUNAR AND PLANETARY LABORATORY

February 19, 1974

Dr. Steve Maran
Code 683
Goddard Space Flight Center
Greenbelt, MD 20771

Dear Steve:

Now that the comet has faded away I want to tell you that despite our every effort we were not able to obtain a spectrum of the comet in the near infrared. There were two major reasons for this: the lack of intensity and the bad weather in Tucson after perihelion. We list the telescope time which we had scheduled, and during which we observed the comet, in Table I.

Before perihelion we simply could not track the comet into daytime. During our effort at the 90", Dec. 15-Dec. 18, we picked the comet up every morning but could not track it more than half an hour into dawn. With our broad bandpass of about 100-500 cps, which is necessary for our interferometer operation, we could not detect a signal.

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I want to ask your permission to use the money that was not used up in the study of the comet for laboratory ice spectra. This work should be quite appropriate for cometary studies and will be needed for the interpretation of any future spectra. We wish to run CH_4, NH_3 and H_2O ices in reflection as a function of temperature, and possibly in transmission. Dr. John Ferraro, a distinguished visiting scientist from Argonne National Laboratory, will be helping me on that project.

I hope this will meet with your approval; if not, please let me know.

With best regards,

Uwe Fink