INFRARED OBSERVATIONS OF THE PLANETS

Final Report

March 1, 1973 to February 28, 1974

University of Arizona
Tucson, Arizona 85721

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Principal Investigator

Introduction

The planetary observations carried out under this grant can be divided into three parts. The first is a continuation of infrared photometry at all wavelengths accessible from the ground, started back in 1964 when we made the first measurements of the infrared emission of Saturn. Some of the more significant results obtained will be briefly summarized below. The second part is a continuation of high resolution infrared mapping of Jupiter with special emphasis at 5 microns. Progress in this area will also be briefly summarized. The third area is a special effort made to obtain extensive infrared observations of Comet Kohoutek. Again we will briefly summarize these results.

I.

Ten years ago we discovered the anomalous infrared behavior of the planet Titan. Since that time we have made numerous observations, both at 10 and 20 microns. Recently, we were able to extend these observations to 34 microns and to include several narrow band filters. In order to compliment these long wavelength data the first good job of near infrared photometry was carried out. All these results were published[1] and now constitute a body of information which has significantly altered our knowledge and understanding of the complex atmospheric phenomena occurring on this large satellite of Saturn.

Similar observations of the Galilean Satellites have been made but here the results are not so exciting. In addition we have used the improved sensitivity and larger wavelength coverage to make additional observations of other planets. These include Mars, Jupiter, Saturn, Uranus and Neptune. Some of these results are not yet published.

[1] "Infrared Photometry of Titan" The Astrophysical Journal Letters 190, L143-L145, 1974, F.J. Low and G.H. Rieke.

II. High-Resolution Mapping

This project was begun several years ago when the hot equatorial band was discovered at 20 microns. Subsequently, the complex 5 micron emission was discovered both here and at Cal Tech. With the assistance of Professor Colin Keay, who was a visitor at this laboratory from the University of New South Wales, new improvements in the observing technique were developed. First results have already been published (Keay, Low, Rieke and Minton 1973). During the period of this report we were able to make improvements in both the sensitivity and angular resolution enabling us to work at the diffraction limit of the 61-Inch telescope. The enclosed figure shows a sample of the highest resolution maps that we have obtained. Our objective during this period has been to obtain complete mapping of the planet on a sufficiently regular basis to accumulate the data necessary to study all of the complex correlations which exist with color photography and with dynamic changes in the atmosphere. This is now a vast body of data which we continue to amass. Because of the large volume of data it was necessary to develop highly efficient computerized processing of the data. It is anticipated that a major publication in this area will be completed in the forthcoming months.

III. Comet Kohoutek

With the much heralded arrival of this "bright" comet we made elaborate plans for observing, starting at the earliest possible time. We were, in fact, the first to make measurements of the thermal emission of Comet Kohoutek, and Dr. Rieke, working in collaboration with Dr. Lee, also of this Laboratory, was able to obtain combined infrared and photoelectric photometry over the period from October to perihelion passage in late December. In the spring of 1974, after perihelion passage, a less vigorous observing program was mounted. However, when all our data are combined with the complete data obtained by Ney at Minnesota, an extraordinarily complete picture of this comet emerges. These results have been, for the most part, already published.

REFERENCES

"High-Resolution Maps of Jupiter at Five Microns", The Astrophysical Journal 183, 1063, 1973, C. Keay, F.J. Low, G.H. Rieke and R.B. Minton.

"Photometry of Comet Kohoutek (1973f)", Nature 248, 737-40 (1974), G.H. Rieke and T.A. Lee. PAPER INTENTIONALLY OMITTED

"Infrared Photometry of Titan" The Astrophysical Journal Letters 190, L143-L145, 1974, F.J. Low and G.H. Rieke. PAPER INTENTIONALLY OMITTED

"Infrared Observations of Comet Kohoutek", Proceedings Comet Kohoutek Workshop, Marshall Space Flight Center (1974), G.H. Rieke, F.J. Low, T.A. Lee, W. Wisniewski.

"High-Resolution Maps of Jupiter at 5 Microns", Lunar and Planetary Laboratory Communications No. 203, (1975) K.R. Armstrong, G.H. Rieke, A.H. Taylor, R.B. Minton and F.J. Low, in press.
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THE UNIVERSITY OF ARIZONA
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LUNAR AND PLANETARY LABORATORY

July 18, 1974

ERRATA

Mr. A. Gary
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Dear Allen:

Ed Ney has just notified me that his reported beam size is in error. I would therefore like to change the discussion in the paper I just submitted. In the first paragraph on page 2, where I say "Ney used a 20 arcsec square aperture; in addition to the . . ." I want to substitute:

"Ney (private communication) used a 27 arcsec square aperture; in addition to the normal corrections for beam size, a correction of about 15% to allow for the different beam shape should be made. Ney's calibration is also about 15% brighter than ours. Finally, the separation between measurement and reference beams is larger for Ney's work, also making the comet appear brighter; from scans of the central region of the comet (Rieke and Lee 1974), the appropriate correction is 5 to 10%. Therefore, for comparison with Ney's photometry, our measurements should be multiplied by a factor of about 1.45, or brightened by 0.4 magnitude. With this adjustment and after allowance is made for the difference in beam size, the two sets of data are in very good agreement. Observations similar to Ney's were also made by Gatley et.al. (1974)."

Yours,

George Rieke

GHR/kcb

Infrared Observations of Comet Kohoutek

G.H. Rieke
F.J. Low
T.A. Lee
W. Wisniewski

University of Arizona

Because the infrared radiation of comets is dominated by thermal emission of dust grains, infrared photometry is a powerful tool for studying cometary dust. However, since the techniques for infrared observing have developed fairly recently, very few comets have been observed in this spectral region. The extensive record of the behavior of Comet Kohoutek (1973f) in the infrared is unique and should result in a substantial increase in our understanding of these objects.

Photometry of Comet Kohoutek before perihelion passage has already been described (Rieke and Lee 1974). In contrast to the behavior after perihelion passage, which will be described in detail below, during this period the comet evolved without abrupt changes and along lines suggested by the much less detailed infrared studies of earlier comets. The nucleus of the comet was not exceptionally large and, compared with Comet Bennett (1969i), Comet Kohoutek ejected relatively little dust; these two facts adequately explain why Comet Kohoutek was much fainter than the early predictions. The spectrum did not show a "silicate" emission feature until the comet came within 1.5 AU of the sun. Within this heliocentric distance, the absorption efficiency of the dust grains in the visible remained constant at about 80%. The infrared color temperature exceeded the temperature that would be attained by gray, conducting spheres at the same heliocentric distances, indicating that the emissivity of the dust grains was substantially less than 80% in the middle infrared.

More recent photometry of Comets Kohoutek and Bradfield (1974b) is summarized in tables 1, 2 and 3. The measurements were carried out under procedures described in the previous article. Because a system of winter storms coincided with perihelion passage, we have no measurements of Comet Kohoutek near this time. Fortunately, the observations described by Ney at this workshop cover the interval near perihelion thoroughly with a slight overlap with our data at either end. The combination of both sets of data provides a complete record of the photometric behavior of Comet Kohoutek. In comparing Ney's infrared data with ours, allowance should be made for some small differences in observing procedure and calibration. Ney used a 20 arcsec square aperture; in addition to the normal corrections for beam size, a correction of about 15% to allow for the different beam shape should be made. In addition, Ney's calibration is about 15% brighter than ours. Finally, the separation between the measurement and reference beams is larger for Ney's work, also making the comet appear brighter; the correction to be applied for this difference depends on a number of experimental details, but from scans of the central region of the comet (Rieke and Lee 1974) we estimate it to be 5 to 10%. Therefore, for comparison with Ney's photometry, our measurements should be multiplied by a factor of about 1.45, or brightened by 0.4 magnitude. Observations similar to Ney's were also made by Gatley et.al. (1974).

Infrared photometry of three comets at heliocentric distances near 0.6 AU is shown in figure 1. Although the spectra are similar, closer inspection shows significant differences in the strength of the "silicate" emission at 10μ (3×10^{13} Hz), with Comet Bennett having the most pronounced spectral feature. Between 3 and 5μ, the color temperature of Comet Bradfield is only slightly above the equilibrium temperature for gray, conducting spheres, while the color temperature of Comet Bennett over this spectral range substantially exceeds the equilibrium temperature. Comet Kohoutek is intermediate in this regard.

The behavior of Comet Kohoutek after perihelion passage is shown in figure 2. The infrared photometry is compared with photometry before perihelion passage at comparable heliocentric distances. Because of the reduced geocentric distance of the comet, it would be expected to be about 20% brighter after perihelion passage. This correction has not been applied to the data in figure 2. Slight variations in the width and height of the 10μ emission feature were suggested by the pre-perihelion passage measurements, but the more recent data show a much larger and definitely significant change between 0.66 and 0.88 AU heliocentric distances. At the same time, changes appear to have taken place near 20μ (1.5×10^{13} Hz). In contrast to the behavior before perihelion passage, the albedo of the dust grains may have fluctuated, with the largest departure from the mean value occurring on January 16 (0.66 AU).

Thus, observations at comparable heliocentric distance show variations in the infrared spectra both from comet to comet and, in the case of Comet Kohoutek, as a function of time. Changes have also been seen in the albedo of the dust grains. It appears that the nature of the dust ejected by the nucleus is different for different comets and can even change with time as a given comet evolves. These changes can occur rapidly, with time scales of less than one week and over changes in heliocentric distance less than 0.2 AU.

Both in the infrared and visible, Comet Kohoutek faded rapidly as it left the sun. After January 16, it was substantially fainter at all wavelengths than it had been at the same heliocentric distances approaching the sun. However, the brightness in the U, B, and V bands, which are dominated by gaseous emission lines, did not decrease as dramatically as at the wavelengths dominated by reflection and emission by dust.

Although other possibilities may exist, the simplest explanation of the changes we have observed in Comet Kohoutek is that the nucleus contains pockets or layers of frozen gas and dust with different properties. As these pockets or layers are exhausted and new ones exposed, the composition of the comet ejecta can undergo abrupt changes. The initial predictions that Comet Kohoutek would be spectacular were based on its being relatively bright when it was far from the sun. However, the brightening was anomalous and the diameter of the nucleus was overestimated (Rieke and Lee 1974). Mendis and Ip (1974) have suggested that this brightening was caused by the exposure of a layer or pocket of volatile material which quickly evaporated from the nucleus.

Therefore, the hypothesis that cometary nuclei contain layers or pockets of different compositions can explain many of the phenomena exhibited by Comet Kohoutek. Abrupt changes and unpredictable behavior have been observed in many other comets, indicating that their nuclei are similar to Comet Kohoutek in this respect. This possibility should be given serious consideration in future studies of the origin and nature of comets.

The infrared observations show that silicates play a role in cometary dust. However, the 10μ emission feature is much weaker in Comet Kohoutek than would be expected from silicate grains unless appreciable numbers of the grains are larger than 5μ in diameter (Hunt and Logan 1972). The presence of many large silicate grains would be hard to reconcile with the elevated brightness temperature in the 3-5μ region and with theories regarding the development of type II (dust) tails. It is more likely that cometary dust contains other materials besides silicates.

The changes in the infrared spectrum might be caused by changes in the size distribution or composition of the grains. In the case of Comet Kohoutek, the development of an antitail and the infrared spectrum of the antitail described by Ney at this workshop show the presence of large grains. However, if the grain diameter is the only variable, the elevation of the 3-5μ color temperature should be correlated with the strength of the 10μ emission feature. Such a correlation is not apparent for Comet Kohoutek and is clearly absent in the three-comet comparison shown in figure 1. Therefore, variations in the composition of the dust probably account for some of the infrared behavior of comets.

In summary, our observations indicate:

1. The absorption efficiency of the dust in Comet Kohoutek was about 80%. The infrared spectrum showed weak silicate emission features at 10 and 18μ and an elevated color temperature between 3 and 5μ.

2. Although silicates are the only material definitely identified in cometary dust, significant amounts of other materials are probably also present.

3. The infrared spectra, and therefore the nature of the dust, varies from comet to comet.

4. Rapid changes in the infrared spectrum of Comet Kohoutek indicate that material of different compositions is found in layers or pockets in the nucleus.

We thank K.L. Day for helpful discussions. This work was supported by NASA and the NSF.

REFERENCES

Gatley, I., Becklin, E.E., Neugebauer, G., and Werner, M.W. 1974, preprint.

Hunt, G.R., and Logan, L.M. 1972, App. Optics 11, 142.

Maas, R.W., Ney, E.P., and Woolf, N.J. 1970, ApJ (Letters) 160, L101.

Mendis, D.A., and Ip, W-H. 1974, Nature, 249, 536.

Rieke, G.H., and Lee, T.A. 1974, Nature 248, 737.

Table 1

Photoelectric Photometry of Comet Kohoutek (1973f)

Date (U.T.)	r (AU)	Diaphragms (") 12	31	62	112	157	Magnitudes U	B	V	R	I
Jan 16.1	0.66					X		6.20	5.76	6.53	
					X		6.19	6.53	6.02	6.75	
				X			7.02	7.28	6.75	7.33	
			X				8.24	8.46	7.92	8.29	7.84
		X						10.91	10.04	10.04	
Jan 23.1	0.73					X		7.27	6.66	7.40	
			X				9.58	9.78	9.18	9.36	9.02
		X						12.10	11.58		
Jan 28.1	0.95					X		7.98	7.41	8.14	
			X				10.32	10.51	9.96	10.19	9.75
		X						12.71	12.23		

Table 2

Infrared Photometry of Comets Kohoutek (1973f) and Bradfield (1974b)

Date (U.T.)	Diaphragms (″)			Fluxes (10^{-26} W m^{-2} Hz^{-1})									
				2.2μ	3.6	5.0	8.8	10.3	10.6	11.6	12.6	21	22.5
	13.5	5.5	4.2	(0.6)	(0.9)	(1.0)	(1.0)	(1.2)	(5.0)	(0.8)	(1.0)	(8)	(5)
Jan.16.1*	x			0.85	5.5	20	95	150		142	114	156	171
Jan.25.1*		x		0.05	0.28	1.0	9.4	12.7			13.9	20	17
Jan.28.1*		x			0.17	0.8	7.2	9.9	10.2	11.1	10.3	18	15
Feb. 8.1*			x		< 0.06	0.2	1.4	2.6		3.1	3.0	6.1	3.9
Feb.17.1*		x						0.8	0.9	1.1	0.9		
Mar.16.1†		x			8	29	123	160	168	173	95		
Mar.17.1†		x			10	39	146	176	177		85	66**	45**

* Comet 1973f

† Comet 1974b

** Normalization relative to shorter-wavelength results is uncertain because of high extinction.

Table 3

Additional Infrared Photometry of Comet Kohoutek

Date (U.T.)	Diaphragm (arcsec)	Wavelength (μ)	Bandpass (μ)	Flux (10^{-26} W m^{-2} Hz^{-1})
Jan 16.1	13.5	3.05	0.1	5.5
Jan 16.1	13.5	3.85	0.5	6.8
Jan 16.1	13.5	4.8	0.6	17
Jan 28.1	5.5	17	2	22

Figure 1. Infrared Photometry of Three Comets. The spectra are labelled with the heliocentric distances in AU. The data for Comet Bennett are from Maas et.al. (1970). The observations of Comet Kohoutek were before perihelion passage. The flux values have been arbitrarily renormalized to facilitate comparison of the spectra.

Figure 2. Comparison of Infrared Observations of Comet Kohoutek Before and After Perihelion Passage. The spectra are labelled with the heliocentric distance in AU and the observations after perihelion passage are indicated with the heavier line. The tick marks in log (S) are at intervals of one. The four groups of spectra have been renormalized to avoid confusion, but there has been no renormalization within each group.

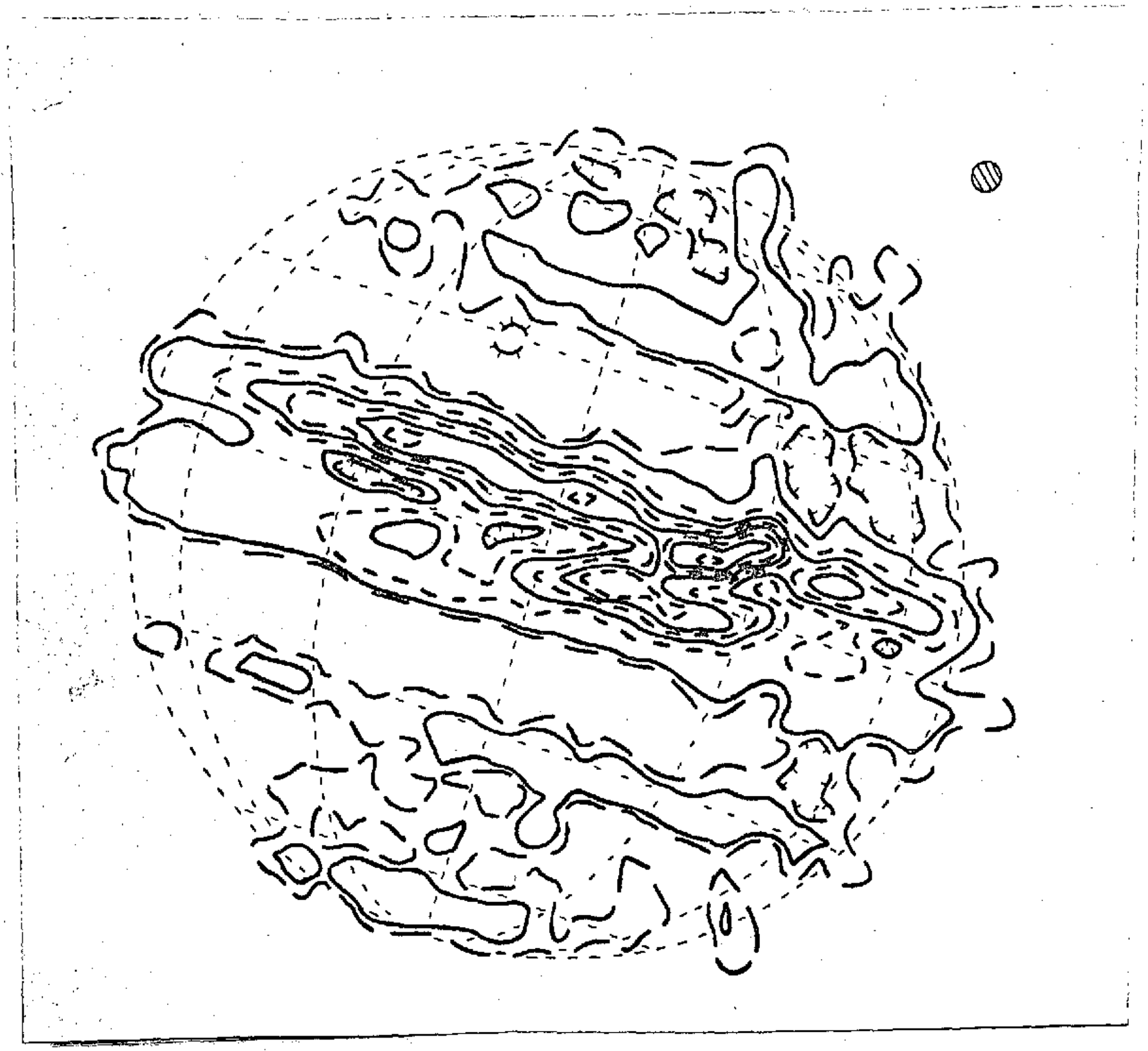

Figure 1 5 surface brightness contour map of Jupiter, June 1973. Contour interval is $5 \times 10^{-15} wm^{-2} Hz^{-1} str^{-1}$ except $2.5 \times 10^{-15} wm^{-2} Hz^{-1} str^{-1}$ between lowest two. Maximum contour is $4.0 \times 10^{-14} wm^{-2} Hz^{-1} str^{-1}$. Light dashed grid shows planetograph coordinate grid and visual outline of disk. $CM_I = 311^{\circ}K$ $CM_{II} = 93^{\circ}$. Beam size is 1.5 arc sec

NO. 203 HIGH RESOLUTION MAPS OF JUPITER AT 5 MICRONS

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ABSTRACT

Preliminary results of 5μ image scans of Jupiter at 1.5 arc sec and 3 arc sec resolution obtained during June 1973 are reported. Thermal emission features within the equatorial region were observed with brightness temperatures in excess of 250 K. Outside this region brightness temperatures as low as 178 K were common, and the regions outside the equatorial band were less bright than observed during the 1972 opposition. The relative color-temperature relationship observed in 1972 was still apparent, but positional agreement between 5μ and visual features was not improved at the higher resolution.

1. Introduction

Image scans of Jupiter at resolutions of 1.5 arc sec and 3 arc sec were obtained during May, June, July, September, October, and November 1973 as an extension of the wide-band 5μ mapping reported by Keay *et al.* (1972). The observations were made with a liquid-nitrogen-cooled InSb detector at the 61-inch telescope of the Catalina Observing Station of the Lunar and Planetary Laboratory, using the same method described by Keay *et al.* Typical rasters of the planet were obtained in 24 min at 1.5 arc sec resolution and 12 min at 3 arc sec resolution. The data reduction differed from that of Keay *et al.* in that the contour maps of each raster were drawn by an IBM 1130 computer. Color photography observations of Jupiter were obtained concurrently with the 5μ observations to facilitate the comparison of features at the two wavelengths. Full coverage of the Jovian surface was obtained at both wavelengths during June 1973, the preliminary results of which are reported here.

2. 5μ Observations

Figure 1 is a surface brightness contour map of Jupiter taken at 1.5 arc sec resolution. The contour levels correspond to monochromatic brightness temperature levels of 205K, 216K, 229K, 237K, 244K, 249K, 253K, 256K, 260K. Figure 2 shows a 120° segment of the Jovian 5μ "surface" obtained by plotting the central 30°-40° segments of four such maps on a cylindrical equal-area coordinate projection. The equatorial region at System I latitudes consists of a prominent band of thermal emission within which are three distinct thermal bands. The warmest sources are seen in a band at 9°N in coincidence with the northern boundary of the Equatorial Zone (EZ). A second, less prominent band of emission sources is located south of the equator within the EZ. A series of small, cold features is seen along the equator. Thermally depressed bands border the equatorial emission region at 30°N and 20°S, and low temperature emission bands are located at 40°N and 30°S. Comparison with beam size measurements indicate that the latitudinal extent of the sources in the central band may approach 1 arc sec. Preliminary reduction of the May 24 1973 data indicates that the bright thermal features in the central band drift at the same rate as visual features.

Complete coverage of the Jovian 5μ brightness distribution is shown in Figure 3. The spatial resolution is 3 arc sec, or 8.7° x 7.6° at the equator. The contour levels are at 1, 2, 4, 6, 8, 10, 20, 30, ...130 with units of $3 \times 10^{-16}\ wm^{-2}Hz^{-1}str^{-1}$ and correspond to monochromatic brightness temperatures of 178, 186, 195, 200, 204, 208, 218, 225, 230, 234, 238, 241, 244, 246, 248, 250, 252, and 254K. The lowest contour is at approximately 1.5 times the background noise level and corresponds to a geometric albedo of 0.1. Note that the brightest regions outside the central band are only 10% as bright as the brightest sources within the central band, and in general, that all areas of the planet outside System I are radiating at lower levels than observed in 1972. There are 18 distinct emission features with brightness temperatures greater than 218K compared to 37 sources with $T_b(5\mu) > 227K$ observed in 1972. The appearance of the lower temperature emission band centered at 30°N is consistent with the 1972 observations which showed a nearly continuous band with $T_b(5\mu) < 205K$. The greatest change in the 5μ appearance of the planet has occurred in the southern hemisphere. The June 1973 observations show no sources with $T_b(5\mu) > 210K$ at the latitude of the STeB, where a total of 12 sources with brightness temperatures as high as 234K were identified at the

Figure 1   5μ surface brightness contour map of Jupiter, June 1973. Contour interval is $5 \times 10^{-15} wm^{-2} Hz^{-1} str^{-1}$ except $2.5 \times 10^{-15} wm^{-2} Hz^{-1} str^{-1}$ between lowest two. Maximum contour is $4.0 \times 10^{-14} wm^{-2} Hz^{-1} str^{-1}$. Light dashed grid shows planetographic coordinate grid and visual outline of disk. CM_I = 311°K CM_{II} = 93°. Beam size is 1.5 arc sec

Figure 2 Equal area cylindrical projection of 5μ surface brightness same latitude in 1972. A thermally depressed band centered at 20°S is only 15% as bright as the same region in 1972. There are no obvious 5μ features at the position of the Great Red Spot (GRS) (350°_{II} to 17°_{II}, -21°S to -28°S) on the June 1973 maps.

3. Comparison with Color Photography

Color photographs obtained on May 27 and June 11, 15, 25 of 1973 using Kodak Ektachrome-EF film and 1 - 1.5 sec exposures were used to construct an equal area map of the visual features on Jupiter. Preliminary drift rates were obtained from this 29-day interval and positions of the visual features were interpolated to their June 18 values. The results are shown in Figure 4 with superimposed 5μ contour levels at T_b = 178, 195, 208, 225, 238, and 244K. Sixteen blue festoons (labeled cyan) are located along the northern edge of the EZn (7°N-9°N) and most have trailing streamers that fade into a light cyan band just south of the equator. The festoons are located on the southern edge of the extended thermal band at 9°N but there is not a high correlation with the most intense sources within the band. White clouds fill the areas between festoons and in general coincide with thermal depressions along the equator. The yellow-ocher NEBZ lies along the northern edge of the high temperature band at 9°N. A yellow band at the southern edge of the EZ and the ocher EZs are located at the same latitudes as the broken thermal emission band south of the equator, but there is no visual evidence of the temperature variations along the band. The higher resolution map of Figure 2 shows the same degree of color-temperature correlation as the 3 arc sec maps.

The relationship between color and 5μ surface brightness appears to be better defined at System II latitudes outside the central 30° band. The warm bands at 40°N and 30°S coincide with the tawny and brown regions of the NNNTeB/NNTeZ and the STeB, respectively, with warmer regions being associated with darker brown. The light red SEBs and white STrZ are coincident with the deep thermal depression at 20°S. White, grey and light red are in general associated with colder regions of the thermal map but there is little evidence of a graduated temperature scale within these three colors.

The only blue spots in System II are at 28°N, 286°_{II} and 297°_{II} longitude, and at the southern edge of each is a white spot. The only significant 5μ feature at that location is a thermal bridge which produces the highest surface brightness at the latitude. A similar bridge spans the most extensive and coldest regions of cold band at 20°S at the longitude of the GRS. Although the average temperature of the GRS is lower than that observed in 1972, it now appears brighter than the adjacent regions of the same latitude because of the reduction in brightness temperature of the SEB_s and STrZ. Each of the three white ovals, FA (33°S, 139°_{II}), BC (33°S, 200°_{II}), and DE (33°S, 340°_{II}) is located at the following edge of a thermal emission peak that is 2.5 times as bright as the adjacent surroundings. One of two red spots (13°N, 344°_{II}) appears to be associated with a prominent thermal feature; the other (18°N, 277°_{II}) is located in a region with no distinguishing thermal features. It may be significant that the former spot was not present on June photographs but was observed in July.

4. Summary

A partial reduction of the 5μ observations obtained during the 1973 Jovian apparition shows that there have been significant changes in the thermal appearance of the planet over the interval of one year. The equatorial region contains sources with higher temperatures than observed in 1972, but the number of discrete sources is lower and the sources are more extended in longitude. The color-temperature relation determined for System I features in 1972 was weaker in June 1973. The higher resolution 1.5 arc sec 5μ maps do not improve the positional agreement of 5μ and visual features. At System II mid-latitudes the 5μ surface brightness is in general 25% or less than that observed in 1972, using the same spatial resolution. However, the relative color-temperature relationship remains valid for these latitudes. The increased sensitivity at 3 arc sec resolution has revealed a possibly significant relationship between the long-lived white ovals and thermal enhancements at their latitude. The existence of such a relationship and the determination of the lifetimes of short-term thermal features, if any, will be determined from the observations made through November 1973. The observations reported here indicate the presence of less direct relationships between thermal and visual features in the Jovian atmosphere than was indicated by the 1972 observations, and show a need for continued monitoring of the planet in the infrared.

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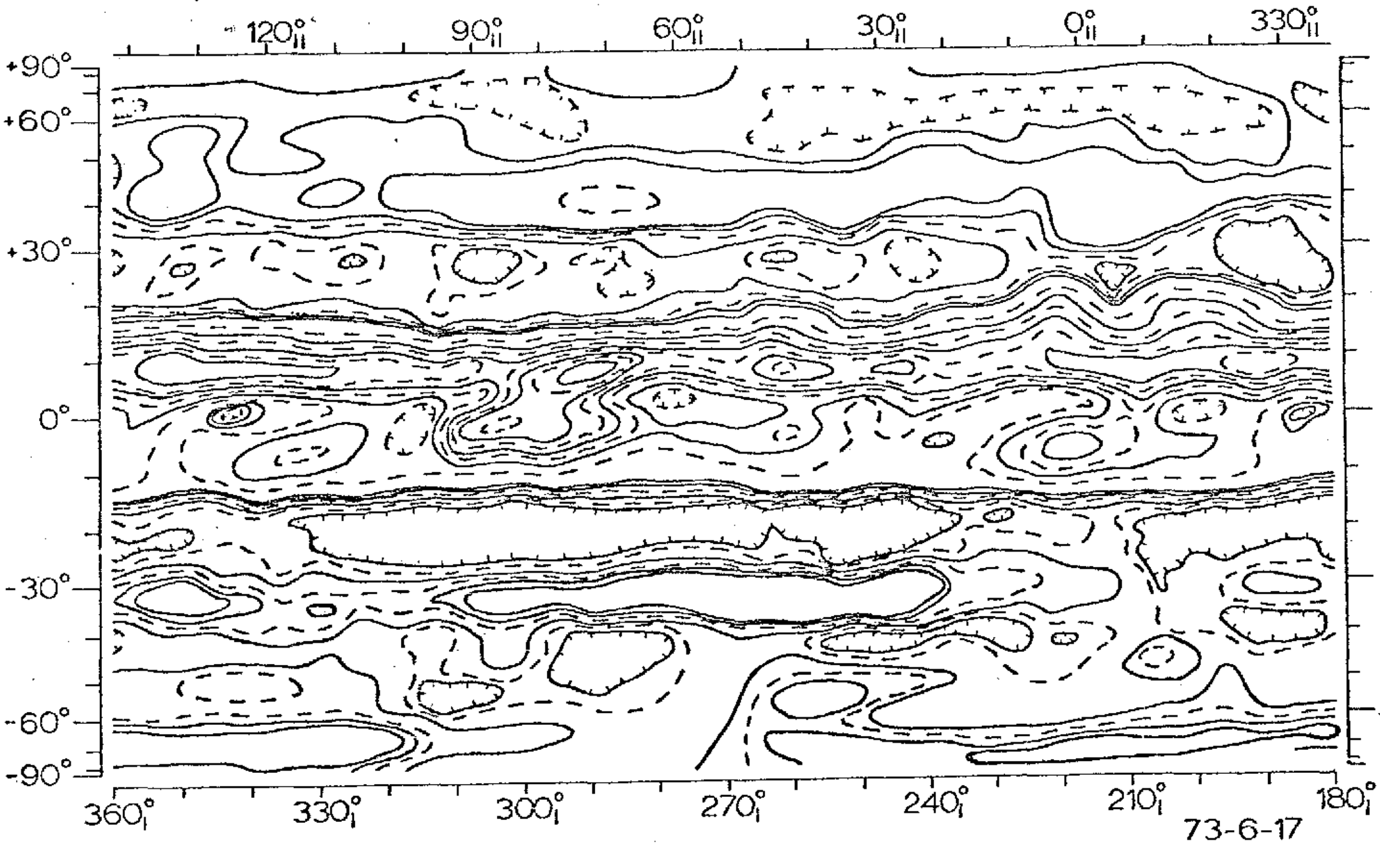

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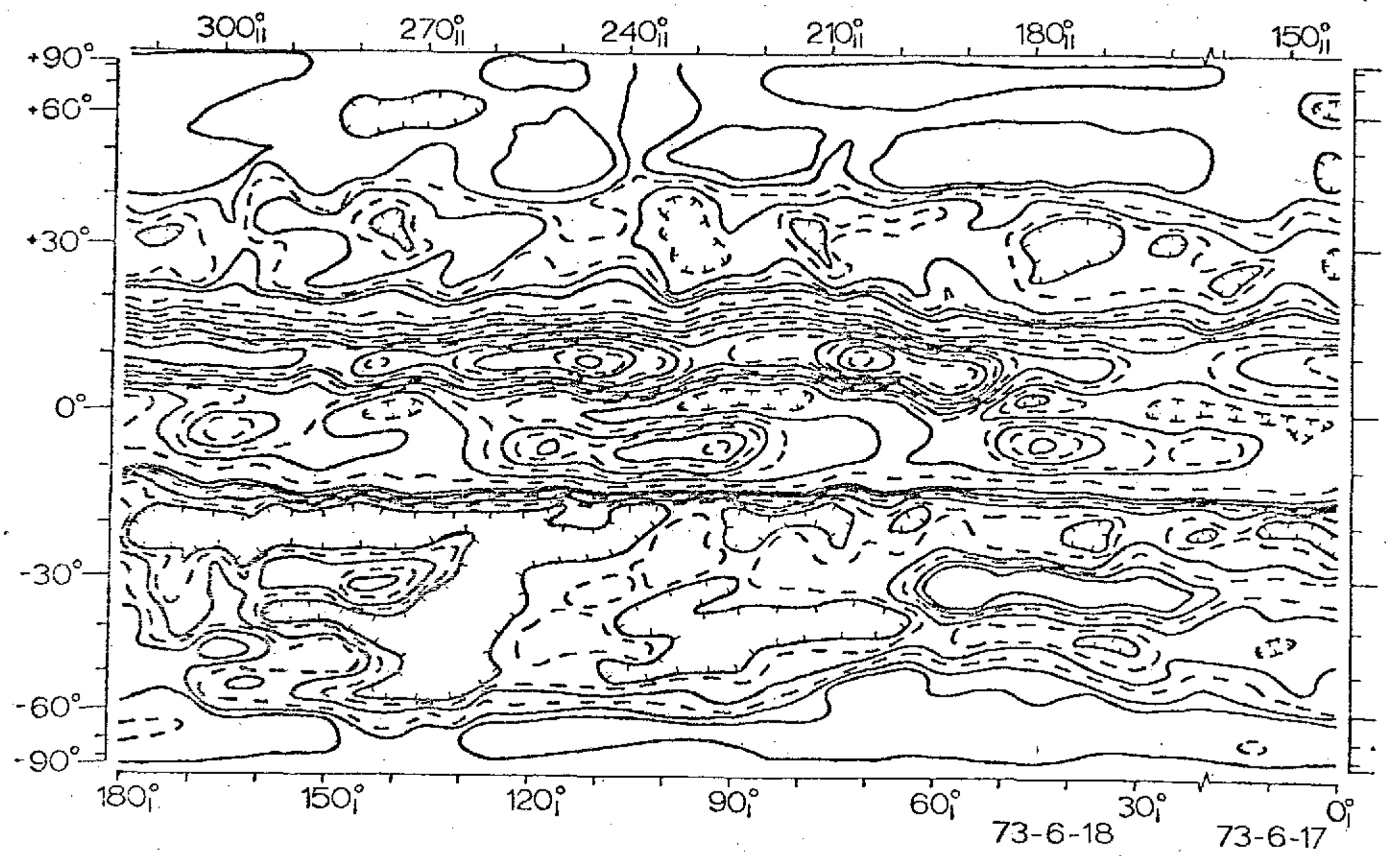

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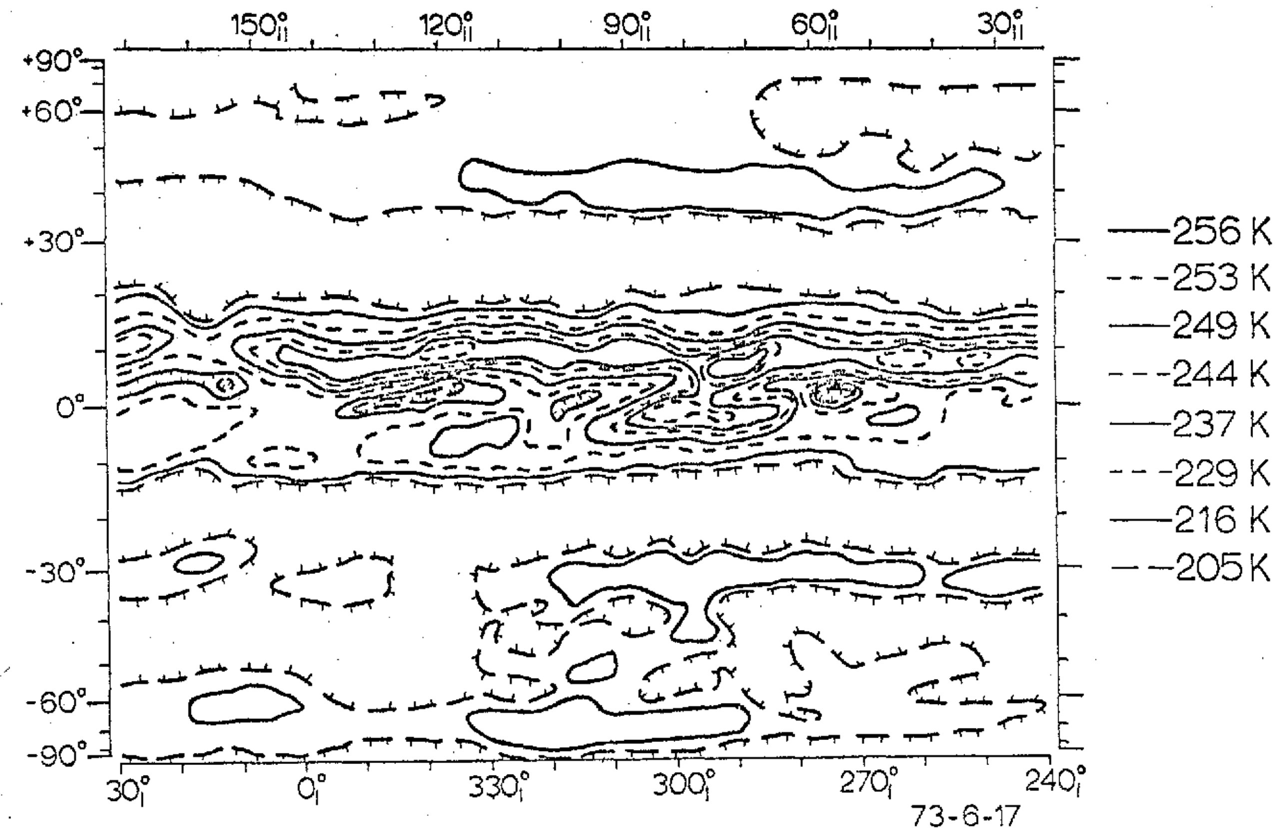
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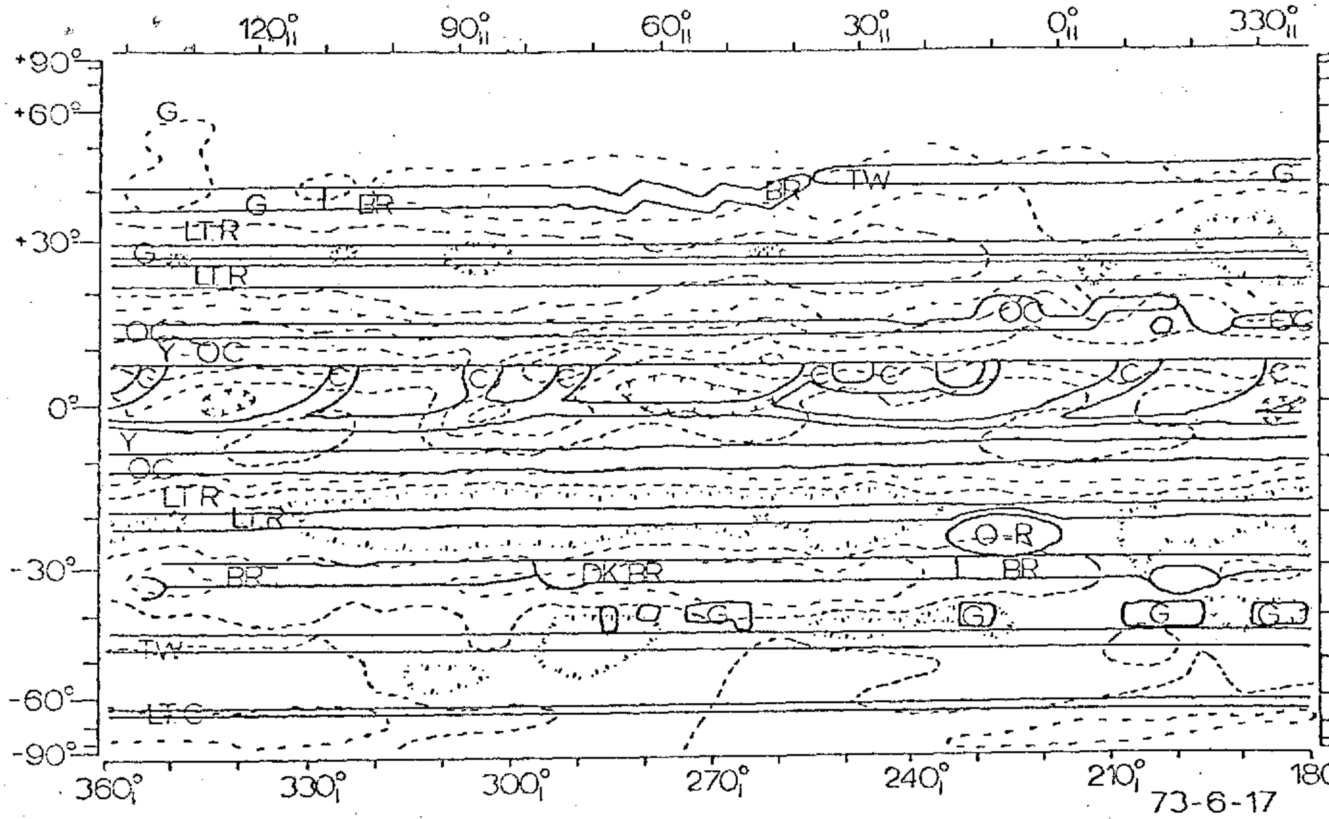
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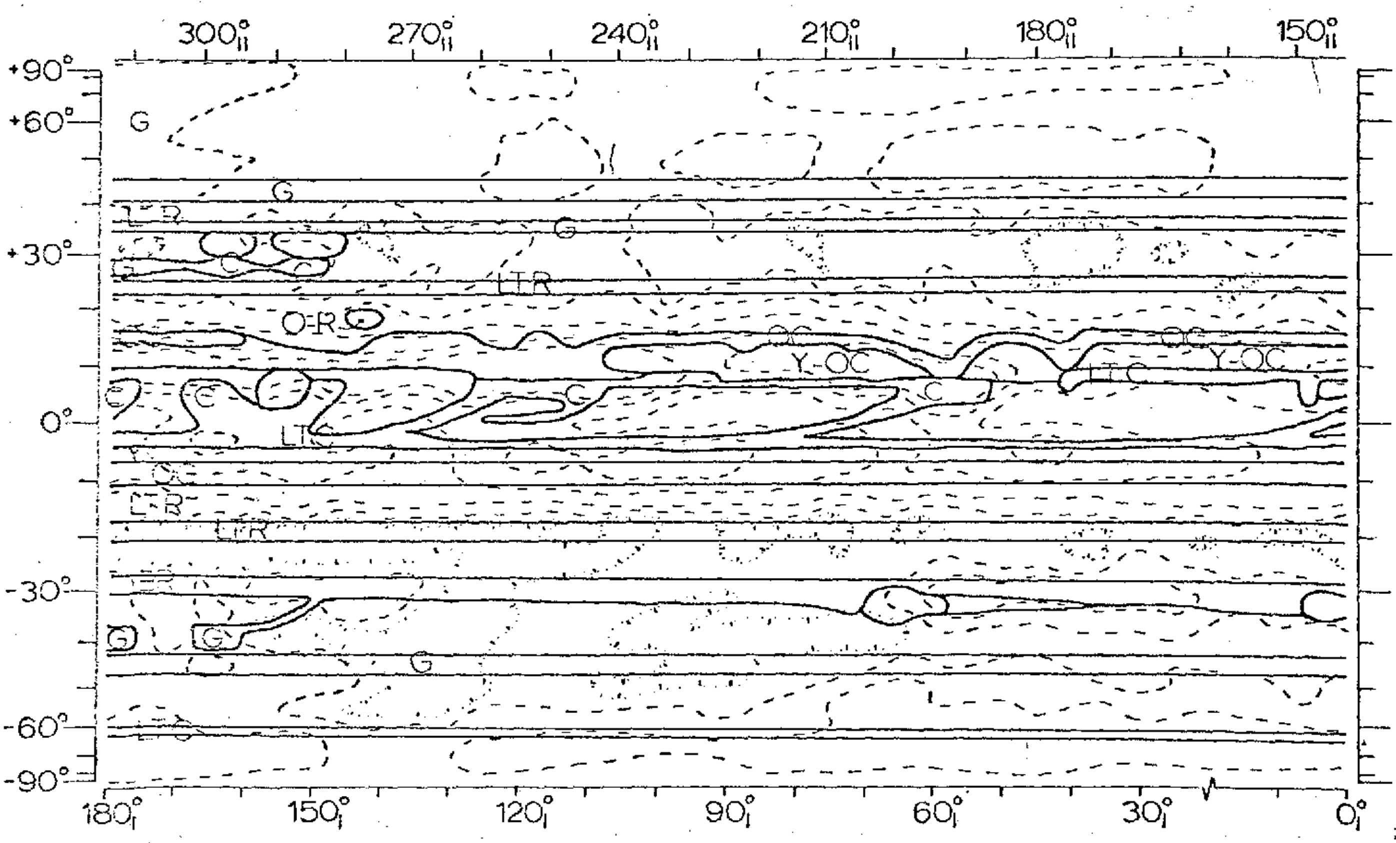
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G
LTR
C
O-R
OC
Y-OC
LTC
180°I
150°I
120°I
90°I
60°I
30°I
0°I