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16. For first-order anisotropy the intensity I_n in the nth LET telescope can be expressed as

$$I_n = A_0 - \mathbf{A}_1 \cdot \hat{\mathbf{T}}_n$$

where $\hat{\mathbf{T}}_n$ is a unit vector along the viewing direction of the telescope. Two of the telescopes are aligned with their viewing directions opposite each other; the remaining two are orthogonal to each other and to the other pair. The resulting set of four linear equations can be solved for A_0 and the three components of $\mathbf{A}_1$.
17. We thank the Voyager Project and the enthusiastic staff of our laboratories at California Institute of Technology (Caltech) and Goddard Space Flight Center (GSFC) for splendid support. Special thanks go to W. Althouse (Caltech), W. Davis, H. Domchick, and D. Stilwell (GSFC), and E. Franzgrote (JPL), who had major responsibilities. Supported by NASA under contracts NAS 7-100 and NGR 05-002-160.

23 April 1979

Infrared Images of Jupiter at 5-Micrometer Wavelength During the Voyager 1 Encounter

Abstract. *A coordinated program to observe Jupiter at high spatial resolution in the 5-micrometer wavelength region was undertaken to support Voyager 1 imaging and infrared radiation experiment targeting. Jupiter was observed over a 5-month period from Palomar and Mauna Kea observatories. The frequency of observations allowed the selection of interesting areas for closer Voyager examination and also provided good short-term monitoring of variations in cloud morphology. Significant global changes in the 5-micrometer distribution are seen over this time period.*

Gillett *et al.* (*1*) discovered enhanced infrared radiation at wavelengths near 5 μm from the central regions of Jupiter's disk, and Westphal (*2*) showed that this thermal radiation originates in localized areas, principally in the equatorial regions. Infrared images of Jupiter at 5 μm, made by scanning a single detector across the planet, were obtained by other investigators (*3*), including Terrile (*4*) who analyzed a 4-year series of these data to show that there are at least three different cloud layers in Jupiter's atmosphere, each characterized by a distinct brightness temperature. The regions of highest 5-μm flux are the deepest observable levels in the planet's atmosphere and correspond to the blue-gray areas in Jovian belts (*5*). The white zones and Great Red Spot are the coldest 5-μm regions.

Voyager 1 afforded an opportunity to make spectroscopic and radiometric observations with high spectral resolution and sufficient spatial resolution to include individual hot regions. In order to predict the global 5-μm appearance of Jupiter at the time of Voyager encounter and the location of specific hot spots for spacecraft observations, we undertook a program of 5-μm imagery of the planet in September 1978 and continued the ground-based observations through the time of Voyager 1 encounter. Terrile (*4*, *6*) had found that the gross appearance of Jupiter changes from year to year, and that while some regions of enhanced 5-μm emission have lifetimes of several months, others form and dissipate on a time scale of days. Planning and sequencing considerations for spacecraft observations at near-encounter required that 5-μm hot spot targets be established with a high degree of certainty as to position and expected degree of "activity" at least 1 month in advance of the encounter date.

Observations were made throughout the apparition of Jupiter with the 5-m Hale telescope at Palomar Mountain and with the 2.24-m telescope at Mauna Kea Observatory in Hawaii in a cooperative program (coordinated by R.J.T.). The technique for observing and image reconstruction has been described (*5*). Observations were obtained at each observatory in blocks of 2 to 5 nights each separated by 2 to 3 weeks starting in September 1978 and continuing through March 1979.

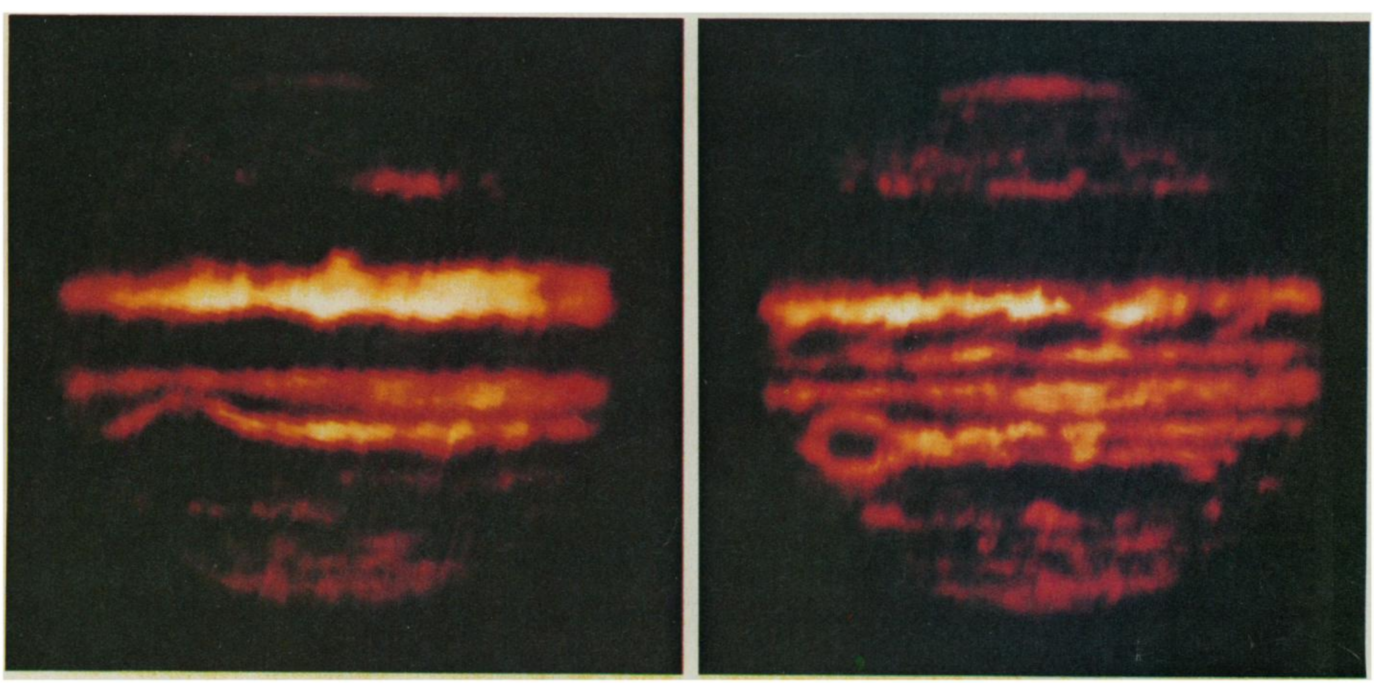

Fig. 1. Comparison of 5-μm images recorded at Palomar on 30 September 1978 (left) and 6 March 1979 (right). These images are shown in false color to bring out the large contrasts between the hottest areas (bright), warm areas (red), and the coldest regions (black). Hot 5-μm features indicate regions clear of overlying cold clouds. The Great Red Spot appears in the lower left of each image as a cold feature with warm regions defining its margin. Significant large-scale changes in warm belt regions can be seen between the two images.

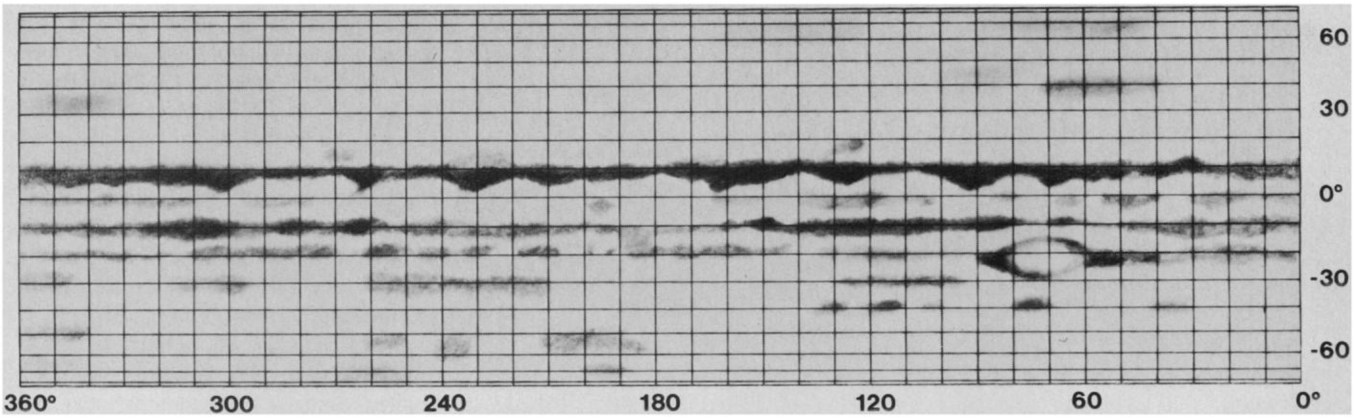

Fig. 2. A cylindrical projection of Jupiter prepared from data in the 5-μm region obtained at Mauna Kea on the nights of 6, 7, and 8 March 1979. Images were obtained at intervals of 5° to 10° longitude for several hours on each night, giving complete coverage with considerable overlap. The longitude scale is for System III (*8*) and the accuracy of the map is thus limited by differential rotation of Systems I and II relative to System III. This is about ± 15° in the equatorial regions because of the differential rotation during the period of observations, and to about ± 3° in the midlatitudes because of the resolution of the images and inaccuracies in transferring the features on the planetary images to the hand-drawn map. The latitude control is based on comparisons of 5-μm features with features seen in Earth-based photographs from which the zenographic latitudes were measured. Latitudes are expected to be limited to ± 5° because of the intrinsic resolution of the 5-μm images (1 arc-second) and drafting errors.

The Palomar data typically show higher signal-to-noise ratio and, depending on seeing conditions, the resolution was as good as 0.7 arc-second. Seeing conditions at Mauna Kea were often comparable although the observing aperture was 1.2 arc-seconds. The resultant two data sets constitute the most complete series of observations of Jupiter at 5 μm over this time scale thus far obtained.

Figure 1 shows two 5-μm images of Jupiter obtained at Palomar on 30 September 1978 (left) and 6 March 1979 (right). The most significant changes that have occurred over this period are a clouding over (therefore cooling) of the north edge of the North Equatorial Belt, formation of a warm region at the equator, and the formation of several new warm components of the South Equatorial Belt, including one which can be seen just south of the Great Red Spot. This figure should also be compared with figure 3 in (*6*), which shows Jupiter partway through this transition.

Figure 2 shows a cylindrical projection map of Jupiter obtained in the 5-μm wavelength region from Mauna Kea data just after the Voyager 1 encounter. The map shows that the regions of highest 5-μm flux, which correspond to a brightness temperature of 260 ± 2 K according to (*4*), are concentrated on the southern component of the North Equatorial Belt. This concentration is characteristic of the appearance of Jupiter for the several months prior to encounter. Areas of weaker emission are plentiful in the southern hemisphere of the planet. At the start of observations, some of these were initially faint in late 1978, but developed as regions of strong 5-μm emission over the observing period. This behavior is especially characteristic of the southern margin of the Great Red Spot as shown in Fig. 1.

Within the northern hemisphere the region above 14° was notably devoid of significant sources of 5-μm radiation at the time of encounter. Numerous very small spots, at the limit of spatial resolution of the 2.2-m telescope and appearing mostly in the 5-m telescope images, were seen at 38°N on the North Temperate Belt. At the high northern and southern latitudes diffuse and faint regions of 5-μm radiation were seen throughout the apparition, and while those shown on the map are characteristic of the time of encounter their placement is uncertain.

The present data base will be useful for detailed studies of the correlation of infrared hot spots with visible features whose morphology at high resolution can now be established with the Voyager images. Continued analysis will yield information on the characteristic lifetimes of various types of 5-μm hot regions, and a high density of data during several periods of observation throughout the apparition affords possibilities for limb-darkening studies at various latitudes (*4, 7*).

Infrared imagery is continuing at Palomar and Mauna Kea in support of target selection for Voyager 2.

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9. We thank T. Clancy, D. Diner, A. Dobrovolskis, and J. Pechmann for assistance. This report presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract NAS 7-100, sponsored by NASA. Work at the University of Hawaii was also supported by NASA under contract NASW 3159.

23 April 1979