# OBSERVATIONS OF JUPITER'S CLOUD STRUCTURE NEAR 8.5 $\mu$

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**Abstract.** Measurements of the distribution of thermal flux along polar and equatorial scans across Jupiter suggest that the increase in brightness temperature near 8.5 $\mu$ observed by Gillett *et al.* may be caused by flux coming from near the cloud tops. Other possible sources are discussed and observational tests suggested which should clarify the thermal structure of the upper atmosphere.

In a recent paper, Gillett, Low, and Stein (1969) (referred to as GLS in this paper) have discussed a low-resolution spectrum of Jupiter. The observations indicate a large increase in brightness temperature from about 9.5 $\mu$ to 7.5 $\mu$. In their discussion, they point out that in the region from 8.3–9.3 $\mu$ there is no obvious source of absorption above the cloud deck. The possibility that a window in the Jovian atmosphere might exist at these wavelengths led to an observational program at high spatial resolution.

On 4 August 1969, equatorial and polar scans of Jupiter were made with the 200-inch Hale telescope. Figure 1 shows data recorded at 8.2–13.5 $\mu$ (lower curve) and 8.2–9.2 $\mu$ (upper curve). The scans are displayed with a linear flux ordinate and a 8.1–9.2 $\mu$ brightness temperature scale. Also shown in Figure 1 is a photograph, on the same scale, of Jupiter taken in April 1969. These data were taken with a 2.5 arc sec circular diaphram.

## 1. Discussion

The correlation of the 8.2–9.2 $\mu$ scan with the gross cloud structure is remarkable and suggests that the flux structure is either closely related to the albedo variation in the visible region or that the effective radiating region is at a different height over the dark areas than over the light areas.

Several models of the temperature-opacity structure of Jupiter are compatible with this data. One model, following GLS, would separate the temperature-opacity structure above the clouds into three domains: (1) the region from 7.2–8.2 $\mu$ where the brightness temperature is $\approx$140 K, and where, since this is a region of high methane absorption, the opacity is probably also high; (2) the region from 8.2–9.5 $\mu$ where the temperature is $\approx$135 K, and the opacity is likely to be low. It is in this region that these observations have shown that the flux structure is strongly correlated with the visible albedo; and (3) a region from 9.5–12 $\mu$ where the temperature is $\approx$125 K, the opacity is probably due to ammonia and very high, and the flux structure is subdued but definitely correlated with the visible albedo.

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Looking at each of these wavelength regions in detail, it can be seen that the strong methane absorption band which occurs in the 7.2–8.2 μ region should increase the opacity and limit the effective radiating region to high in the atmosphere. GLS have interpreted the high temperature in the 7.2–8.2 μ region to be due to an inversion. Such a temperature structure could be supported by absorption of sunlight in the 3.3 μ

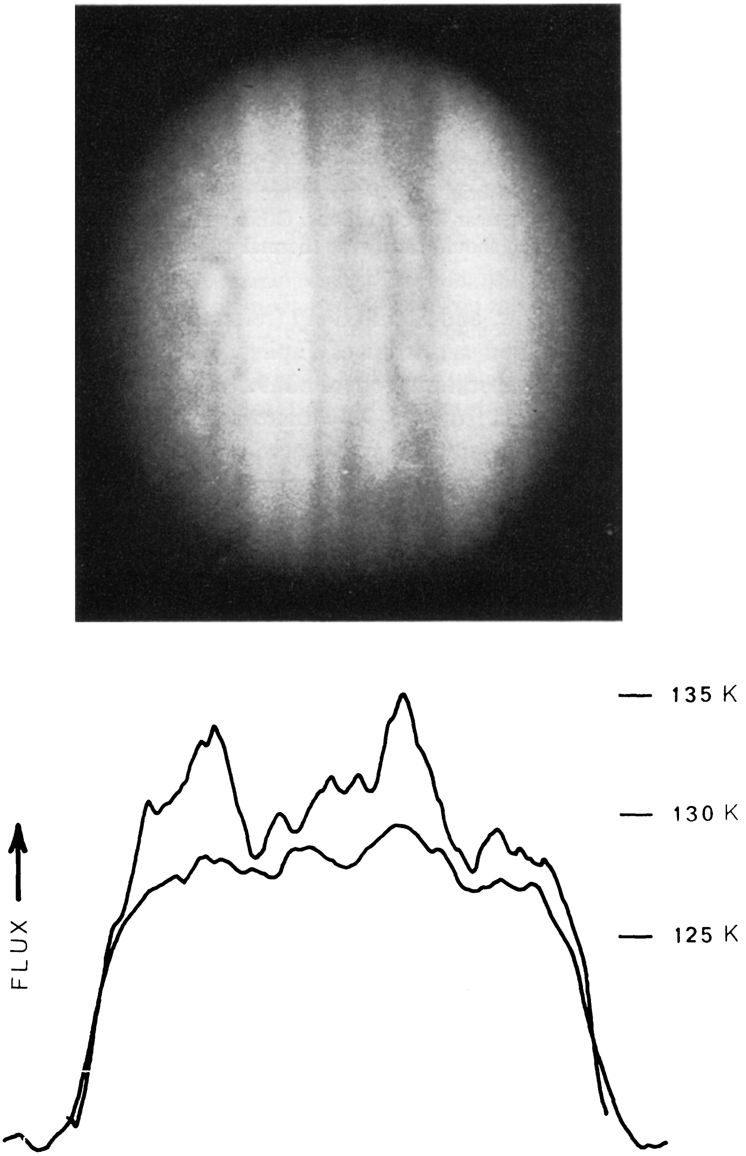

Fig. 1. Polar scans of Jupiter, respectively at 8.2–13.5 μ (lower curve), and 8.2–9.2 μ (upper curve). See text for further description. The photograph shows at the same scale the appearance of Jupiter some four months earlier, with a pattern of cloud belts similar to those on the date of the scans.

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methane band. They propose that the temperature decreases with height until it reaches $\leqslant 115$ K then increases again to $\geqslant 145$ K.

If such an inversion exists, then the flux observed in region (2) 8.2–9.2 $\mu$ and shown in Figure 1, top curve, could come from a region either above or below the 115 K level. If it comes from above the inversion then one must explain the strong correlation with the visible albedo. If however, it comes from below the inversion, it could then come from a region near the cloud tops and the structure seen in Figure 1 would be due to either variations in cloud height, with the dark areas low and the bright areas high, or the structure could be due to localized heating due to albedo variations. A recent paper by Ingersoll and Cuzzi (1969), has suggested that the light bands are clouds in the top of upward moving convection cells and that the dark bands are relatively clear areas in downward moving regions. Thus it is very likely that the white bands would be higher than the dark bands.

In the GLS model, region (3), the flux observed from 9.5–12 $\mu$ would come from a region where the ammonia concentration is high and yet near enough to the cloud tops to still have some apparent flux structure. The equatorial scans from 8.2–9.2 $\mu$ show about the same limb darkening character as the 8.2–13.5 scans. This observation is compatible with the 8.2–9.2 $\mu$ flux coming from about the same region as the 9.5–12 $\mu$ flux since most of the energy observed from 8.2–13.5 $\mu$ comes from the 10–12 $\mu$ part of the spectrum.

An alternate model, in which the 8.2–9.2 $\mu$ flux comes from above the proposed inversion will require some special source of opacity which is not effective at longer wavelengths, where there is strong evidence (GLS) that the opacity is due to ammonia, which must be below a 115 K inversion level. Also such a model will require significant 20–50 $\mu$ opacity so that the region could be locally heated from below by the flux from the band structure. Although molecular hydrogen and helium (Trafton, 1967) could possibly furnish this opacity, it is difficult to see why the flux contrast would be greater than that observed (lower curve Figure 1) in region (3), which presumably is closer to the clouds in this model and has even higher hydrogen opacity.

Another model would abandon the temperature inversion and simply allow the 7.4–8.2 $\mu$ flux to come from even deeper than the 8.2–9.2 $\mu$ flux. It is hard to see how this could be the case since it would require the methane absorption in region (1) to be much less than the calculated value; however, this possibility exists since no laboratory measurements under Jovian conditions are available. Measurements of Jupiter in the 7.4–8.2 $\mu$ region, with high spatial resolution are possible and will quickly settle this point. If limb brightening is found, then the inversion proposed by GLS is confirmed. If, with this limb brightening, no flux structure correlated with that found in region (2) in this investigation is seen, then it is most likely that the flux in region (2) is coming from below the inversion and below the level of region (3). If on the other hand correlative structure is found, then it is possible that the flux from region (2) is coming from above the temperature minimum.

If no limb brightening is observed in region (1) then it seems likely that the flux in region (1) is coming from below that in regions (2) and (3) and that there is severe difficulty with the methane absorption calculation. In this case the large flux observed

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by GLS in region (1) may be coming from localized emission from the North Equatorial Belt in a manner similar to that seen at 5 $\mu$ (Westphal, 1969).

## 2. Summary

Large spatial variations in the 8.2–9.2 $\mu$ flux from Jupiter which are strongly correlated with the visible albedo have been observed. The most likely source of the flux in this wavelength region is radiation from material near the top of the cloud deck. The variations in flux can be due either to variations in cloud height or to some process closely related to the distribution of visible albedo. Measurements of limb darkening and flux structure in the 7.2–8.2 $\mu$ region will allow a choice between several possible models of the Jovian temperature-opacity profile above the cloud deck.

## References

Gillett, F. C., Low, F. J., and Stein, W. A.: 1969, *Astrophys. J.* **157**, 925.
Ingersoll, A. P. and Cuzzi, J. N.: 1969, *J. Atmospheric Sci.*
Trafton, L. M.: 1967, *Astrophys. J.* **147**, 765.
Westphal, J. A.: 1969, *Astrophys. J.* **157**, L63.

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