Reports

Jupiter: An Unidentified Feature in the 5-Micron Spectrum of the North Equatorial Belt

Abstract. *Grating spectra of the North Equatorial Belt of Jupiter between 4.5 and 5.1 microns, obtained with a nominal resolving power of 180, are presented. An absorption feature centered at 4.73 microns and not due to a known constituent has been found. Its possible identification is discussed.*

Observations by Gillet *et al.* (*1*) have shown that the jovian atmosphere is highly transparent to radiation in the spectral range from 4.6 to 5.2 μ. The brightness temperature characteristic of the North Equatorial Belt (NEB) is, on the average, about 240°K, although localized emission within the NEB with a brightness temperature as high as 310°K has been reported (*2*). Thus it is now possible to study the deep levels of the jovian atmosphere.

In order to make a preliminary spectral reconnaissance of the 5-μ spectrum of Jupiter, the two-beam 50-cm Ebert-Fastie spectrometer described by McCammon *et al.* (*3*) has been fitted with a grating (150 grooves per millimeter) blazed at 4 μ and a Pb-Se photoconductive detector. Spectral scans of Jupiter and of a number of bright stars were obtained with this instrument attached to the Cassegrainian focus of the 200-inch (500-cm) reflector on 14 and 15 June 1970. The matched entrance and exit apertures were chosen to give an angular resolution of 5 arc sec and a spectral resolving power of 180. The wavelength calibration was obtained from a polystyrene film standard and from terrestrial H_2O absorption features.

The most prominent features by far in all the spectra obtained are caused by terrestrial H_2O. In order to isolate possible spectral differences among the objects, various ratios between their spectral flux distributions have been considered. Ideally, the spectral intensity ratios between two objects at the same air mass would not contain terrestrial H_2O features if the H_2O distribution were constant in time and independent of direction. Unfortunately, this is not the case in practice, as is shown in Fig. 1. A spectrum of α Boo taken on 15 June 1970, normalized with respect to another spectrum of α Boo taken at nearly the same air mass but on the preceding night, shows uncompensated terrestrial features at a wavelength above 4.9 μ.

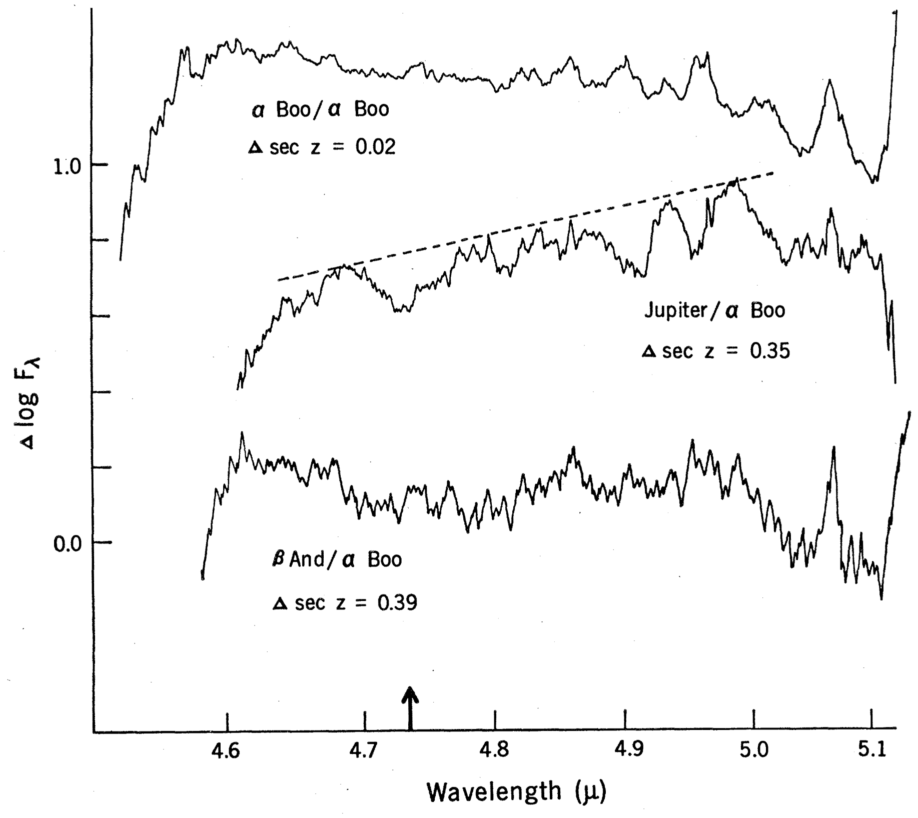

Fig. 1. The spectral intensities F_λ of α Boo, Jupiter's North Equatorial Belt, and β And, each divided by a single scan of α Boo. The jovian spectrum is an average of four scans obtained on two successive nights. The mean differences in air mass (secant of zenith distance *z*) between the objects are indicated. The dashed line corresponds to a color temperature of 300°K.

The spectrum of Jupiter's NEB, also reproduced in Fig. 1, represents the ratio between the average of four individual scans of the planet, obtained on different nights, and one single spectrum of α Boo. Notwithstanding the lower signal-to-noise ratio of the planetary spectrum and the perfunctory compensation for H_2O absorption, the spectrum of Jupiter, in relation to that of α Boo, shows a conspicuous broad dip centered at 4.73 μ. The intensity spectra show that the dip is characteristic of Jupiter and not of α Boo or of the earth's atmosphere (see the spectral intensity ratios of β And shown in Fig. 1). Observations obtained in July 1971, with the same spectrometer but with an improved signal-to-noise ratio, have confirmed the reality of the 4.73-μ absorption feature. These new spectra will be discussed elsewhere (*4*).

Molecules with strong bands near 4.7 μ, which have been suggested as possible constituents of the jovian at-

Table 1. Molecules with absorption bands near 4.73 μ.

Mole-cule	Band	Wave-length (μ)	Refer-ence
HCN	$3\nu_2$	4.73	(*8*)
C_2N_2	ν_3	4.63	(*8*)
CH_3D	ν_2	4.54	(*9*)
GeH_4	ν_3	4.73	(*10*)
SiH_4	ν_3	4.56	(*11*)

mosphere, are listed in Table 1, together with the wavelengths of their band origins. Although only the HCN and GeH_4 bands can strictly be considered as coincidences, the unknown background of the jovian spectrum would not entirely rule out the other molecules listed in Table 1. Objections against the presence in Jupiter of the molecules listed in Table 1 can be raised on the basis of calculations of chemical equilibrium (*5*) or consideration of elemental abundance. Such calculations, however, may not strictly apply to Jupiter.

The feature observed at 4.73 μ could also be produced by the absorption of solid particles, such as ammonium hydrosulfide or ammonium polysulfides [NH_4SH or $(NH_4)_2S_x$], recently postulated (*6*) to be the condensable materials forming a cloud layer in Jupiter at about 225°K. No information regarding the absorption of these ammonium salts seems to be available. However, Woeller and Ponnamperuma (*7*) have recorded the time development of the spectrum of a reaction involving HCN and NH_3. The polymer formed as the end product of the reaction, after removal of unreacted gases, shows an absorption feature at about 4.72 μ which is in fact more conspicuous than the HCN band in the unreacted mixture. The 5-μ spectrum of Jupiter presented here has thus brought into new relevance laboratory experiments of the kind that Woeller and Ponnamperuma (*7*) have performed.

The spectrum of Jupiter presented in Fig. 1 also shows the following characteristics:

1) The spectral gradient corresponds to a color temperature of 300°K if the color temperature of α Boo is taken to be 3600°K. The brightness temperature implied by the measured irradiance at 4.8 μ is $\sim$ 250°K. The difference between these color and brightness temperatures is not considered significant.

2) The intensity decreases sharply at wavelengths below 4.7 μ. This decrease is probably the result of absorption in the extremely strong ν_3 band and in the weaker combination bands $2\nu_4$ and $\nu_2 + \nu_4$ of CH_4. The energy emitted by Jupiter in the entire 5-μ window would be between 10 and 15 percent higher if this absorption were not present. Inferences (that is, brightness temperatures) from broadband photometry of standard stars and Jupiter should thus allow for their different spectral energy distributions. The incomplete compensation for terrestrial H_2O absorption and the insufficient signal-to-noise ratio have precluded the detection of any extraneous feature in the jovian spectrum at wavelengths greater than 4.9 μ.

G. MÜNCH
G. NEUGEBAUER

Hale Observatories,
1201 East California Street,
Pasadena, California 91109

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12. We thank Dr. K. Fox for valuable discussions and unpublished information regarding the interpretation of the 5-μ spectrum of Jupiter. We thank G. Tuton, J. Bennett, M. Katz, and K. Kaufmann for technical assistance. Supported under NASA grant NGL 05-002-140. Hale Observatories are operated under the joint auspices of the California Institute of Technology and the Carnegie Institution of Washington.

5 August 1971

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Particle Formation during Water-Vapor Photolysis

Abstract. *Micrometer-sized particles have been produced by the photolysis of water vapor at wavelengths between 1500 and 1700 angstroms. Although the composition of the particles was not determined, the rate of particle production is consistent with the efficient conversion of water photolysis products to particulate matter. Such a process may be of importance in planetary atmospheres.*

This report describes our observation of the formation of particles when H_2O vapor at unsaturated pressure is exposed to ultraviolet (UV) light at a wavelength between 1500 and 1700 Å. Each particle has spheroidal shape, low density, unit positive charge, and a diameter that is determined by competition between the rate of H_2O vapor absorption and the rate of particle sedimentation. When H_2O vapor at a pressure of 10 torr (one-half the saturation vapor pressure) is photolyzed, each UV photon that is absorbed results in an increase in particle mass equal to that of approximately one H_2O vapor molecule. The mass added to particles per photon absorbed is about an order magnitude greater when a mixture of H_2O vapor at a pressure of about 10^{-2} torr in He at a pressure of 300 torr is photolyzed. Presently accepted concepts of H_2O chemistry do not appear capable of accounting for these observations.

The phenomenon of particle formation induced by the illumination of a gas is not, in itself, unusual. In 1869 Tyndall (*1*) described experiments on the vapor of "nitrite of butyl" in which "the chemical action of light" served to "render . . . vapor visible." Since 1869 many observations of light-induced particle formation have been reported. The subject has been reviewed by Mohnen and Lodge (*2*). Observations of this kind can be divided into two classes, depending on whether or not the reaction system contains a species that is supersaturated. Where the reactants are not supersaturated, particles will be formed only if a product species produced by the light can form a polymeric compound with low vapor pressure. The number of gaseous molecules converted to the particle phase is thus of the same order of magnitude as the number of photons absorbed. Tyndall's observations and the formation of aerosols in photochemical smog from SO_2, NO_2, and hydrocarbons (*2*) appear to be in this category. In the second class of gas-to-particle-conversion phenomena, one species is present with a supersaturated pressure. The formation of a suitable condensation nucleus will induce rapid formation of droplets (particles). Since the condensation nucleus need only be a few molecular diameters in size, the