AN OBSERVATION OF JUPITER IN THE ULTRAVIOLET

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RÉSUMÉ. — *On a obtenu un spectre ultraviolet de Jupiter (*1700-4000 Å, *résolution* 55 Å*) au moyen d'un dispositif photoélectrique. Cet unique document est présenté comme une réflectivité géométrique, laquelle est ensuite supposée due à la diffusion Rayleigh par l'hydrogène moléculaire. On en déduit une limite supérieure de la quantité d'hydrogène moléculaire présente au-dessus de la couche de nuages d'une atmosphère de* 11 *km atm.*

ABSTRACT. — *A single photoelectric spectral scan of Jupiter in the ultraviolet is presented in the form of a geometric reflectivity. The reflectivity is then assumed to be due to Rayleigh scattering by molecular hydrogen. An upper limit to the amount of molecular hydrogen above the cloud layer of a 11 km atm. is derived.*

Резюме. — Получен ультрафиолетовый спектр Юпитера (1700-4000 Å, разрешение 55 Å) при посредстве фотоэлектрического устройства. Этот единственный в своем роде документ представлен как геометрическая рефлексивность, которая, затем, предположена являющейся следствием релеевского рассеяния молекулярным водородом. Из этого выведен верхний предел количества молекулярного водорода находящегося над слоем облаков атмосферы в 11 км атм.

A single spectral scan of Jupiter in the ultraviolet was obtained from an Aerobee rocket on July 23, 1963 at 06 h 02 mn U. T. The observation was made with an objective grating stellar spectrometer similar to those described by STECHER and MILLIGAN (1962). The spectral range was from λ 1700 to λ 4000 with 55 Angstrom resolution. The instrument had been calibrated in the laboratory prior to flight so that the absolute flux above the earth's atmosphere was obtained at each point in the spectrum. The accuracy of the flux measurement was primarily determined by the noise in signal which was worse than one would like.

The geometrical reflectivity, p, as a function of wavelength is presented in Figure 1. This was obtained by using the solar flux values given by TOUSEY (1963) and the appropriate Ephemeris values for the necessary geometry. Jupiter was nearly at quadrature when the observation was made.

If we assume Jupiter has a Rayleigh atmosphere in the ultraviolet above the cloud layer, we may immediately obtain upper limits for the column density of any species if the reflectivity is known in terms of optical depth, τ. Using the tables computed by COULSON, DAVE and SEKERA (1960), curves in the p-τ plane were constructed by numerical integration. Additional curves were obtained for isotropic scattering from the available X-Y functions given by MAYERS (1962) and by SOBUTI (1963). These were used to approximate Rayleigh scattering for $\tau > 1$.

The total number of atoms or molecules in a cm^2 column perpendicular to the cloud layer is now obtained from $\tau = n\sigma$ under the assumption of only one constituent. Here n is the number of atoms or molecules and σ is the Rayleigh scattering cross section per atom or molecule. The Rayleigh scattering cross section for molecular hydrogen is given by DALGARNO and WILLIAMS (1962). In Figure 1 three atmospheres of molecular hydrogen are presented each with the assumption of zero reflectivity for the cloud tops. The 7 km. atm. is that of SPINRAD and TRAFTON (1963) obtained from the H_2 quadrupole bands. The 4.6 km. atm. is that of ZABRISKIE (1962) which is also from the H_2 quadrupole bands. The 10.5 km. atm. is the one that best fits the reflectivity measurements. An all helium atmosphere which would produce the same reflectivity would be about 200 km. atm. and can probably be ruled out by pressure considerations (SPINRAD and TRAFTON, 1963).

The above analysis is based on coherent scattering. In the case of most molecular gases including molecular hydrogen this is known not to be the case. Raman scattering from H_2 is one-

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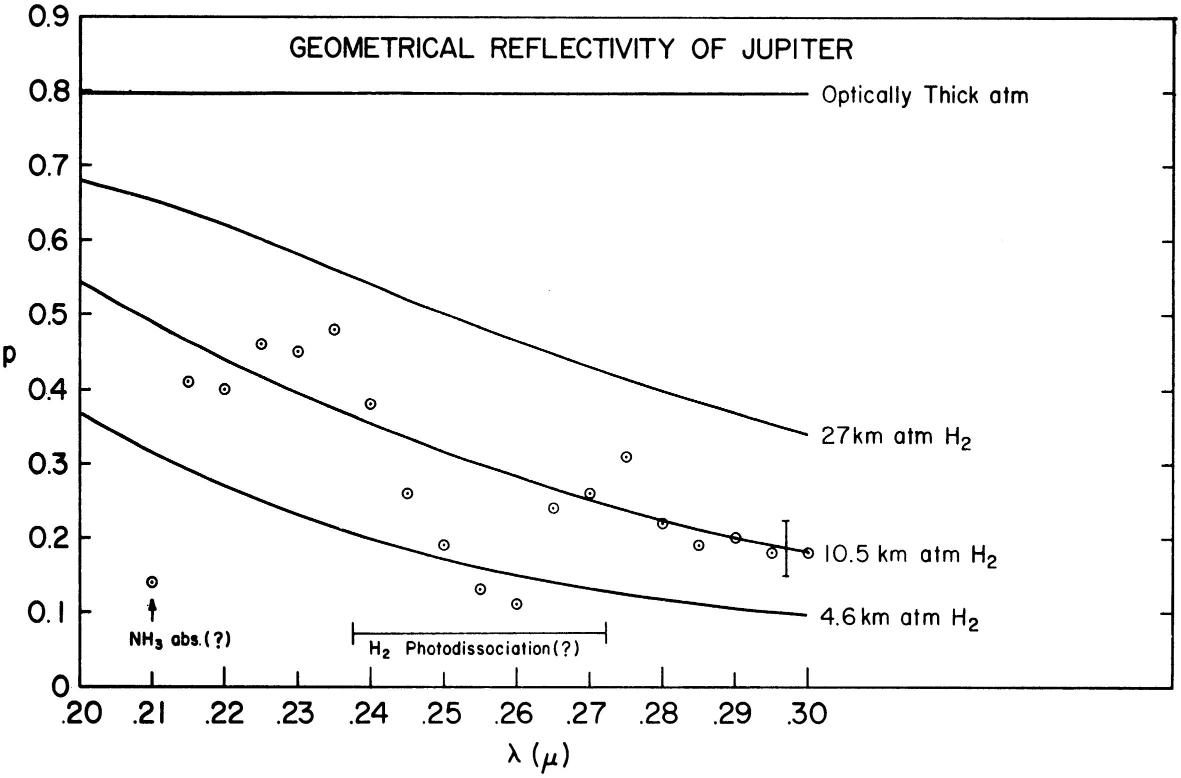

FIG. 1. — The observed geometrical reflectivity of Jupiter, p, as a function of wavelength. The best fit is the 10.5 km.atm. of H_2. The other curves are those of other investigators.

twentieth of Rayleigh scattering at λ 1216 (DALGARNO and WILLIAMS, 1962). Isotropic scattering may be used to approximate this effect by setting the particle albedo equal to 0.95 and comparing it with the result for a particle albedo of unity. In the case of an optically thick atmosphere (HARRIS, 1961) one concludes that 43 % of the incident photons emerge in the Raman lines. The effect which depends on the cross section for Raman scattering in the 2000 to 3000 Angstrom range would be to decrease the reflectivity and give the appearance of less atmosphere.

The absorption feature between λ 2400 and λ 2700 is of course unidentified. If for the sake of conjecture it is assumed to be the forbidden photodissociation of molecular hydrogen, an empirical absorption coefficient may be derived. This may be done by following the path of the photon with isotropic scattering. A particle albedo of unity is equated numerically to the Rayleigh scattering cross section and the particle albedo giving the observed mean absorption depth is determined. The ratio then gives the cross section which is on the order of 10^{-27} cm^2 assuming all H_2.

Below λ 2000 the solar continuum is so weak that no reliable determination of the reflectivity can be made. It appears to be zero which is reasonable since absorption of ammonia begins at 2100 Å and results in almost continuous absorption at shorter wavelengths reaching an optical depth of 10^5 at λ 1216 (KUIPER, 1952) (WATANABE *et al.*, 1953).

One is tempted to make the speculation that Raman scattering can account for the ultraviolet decrease in Uranus and Neptune. The reflectivity curves of these planets reported here two years ago by YOUNKIN and MÜNCH (1962) give the appearance of a conservative Rayleigh atmosphere reduced in the near ultraviolet by the redistribution of scattered radiation by Raman scattering. This assumes that the Raman H_2 scattering coefficient is about two percent that of the Rayleigh scattering coefficients.

A paper on Jupiter which contains a more complete description and additional observational material will appear in the Astrophysical Journal.

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Discussion

C. Sagan (contribution to the article by T. P. Stecher). — Dr. Stecher's observations of Jupiter may have some relevance to Mars. In 1959 Boggess and Dunkelman published a paper in which from a single rocket observation, an albedo of 0.24 was quoted for Mars at 2700 Å. The high value is somewhat surprising because Martian albedos at 3500 Å are only a few percent. But on the same rocket flight an albedo was obtained at the same wavelength for Jupiter. This Jovian albedo is now confirmed by Stecher. I would like to ask Dr. Boggess how he feels about the reliability of Martian ultraviolet albedo.

A. Boggess. — The reliability of the albedo measurement for Mars is very much lower than for the measurement on Jupiter. The flux measured for Mars was about a factor of ten less than that for Jupiter, so that the signal-to-noise ratio was very poor. Moreover, Mars was observed only once, compared to two observations of Jupiter. Finally, there is a slight possibility that the Mars observation was contaminated by radiation from the Pleiades just a few degrees away. For these reasons I have never placed much confidence in the Martian albedo measurement.

C. Sagan. — Ihnat, Phaneuf and I have recently measured the ultraviolet reflection spectrum of simulated Martian surface materials with an integrating sphere. We studied various limonites, hematites and gosthites as indicated by Dollfus' polarimetry. In all cases albedos of only a few percent were found. So if the high Martian albedo stands we must invoke an atmosphere scattering layer on Mars, perhaps connected with the blue haze.

A. Boggess. — It would seem very reasonable to me if the blue haze were essentially opaque at 2700 Å. I am not sure the properties of Martian surface materials are very significant in determining the ultraviolet albedo of the planet.

C. Sagan. — It would be nice, among all this stellar photometry, to obtain a few more ultraviolet observations of planets.

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