PART III

OUTER PLANETS

VARIATIONS IN THE COLOR OF JUPITER

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Abstract. Observations of Jupiter by multicolor photoelectric photometry in 10 narrow bands between 3150 Å and 1.06 μ and in UBV showed a brightening for shorter wavelengths in 1965 relative to 1963. An opposite effect occurred for the band at 7300 Å. These results are consistent with observed activity in the Jovian atmosphere. No obvious correlation could be found between brightness fluctuations and longitude of the central meridian, indicating that the activity was uniform in longitude or occurred on time scales short compared to a month.

1. Introduction

Results of a program of multicolor photoelectric photometry of the planet Jupiter between the dates June 3, 1963, and December 19, 1965, have been reported by Irvine *et al.* (1968a; Paper II) and Irvine *et al.* (1968b; Paper III). Observations were made at both the Le Houga Observatory in France and the Boyden Observatory in South Africa, using 10 narrow bands isolated by interference filters between 3150 Å and 1.06 μ, and also in UBV. The narrow bands were given the designations *v-u-s-p-m-l-k-h-g-e* as indicated in Table I. The present paper examines these data for time variations over the three year observing period.

TABLE I
Effective wavelengths of passbands[a]

Band	*v*	*u*	*s*	*p*	*m*	*l*	*k*	*h*	*g*	*e*
λ_{eff} (Å)	3147	3590	3926	4155	4573	5012	6264	7297	8595	10 635
Halfwidth	145	120	45	90	85	90	160	200	90	770

[a] For details, see Young and Irvine (1967).

2. Analysis

Using a linear least squares fit to the data of Papers II and III we found generally good agreement for the magnitudes at unit distance and zero phase $m(1, 0)$ for each filter between the two sites. In order to investigate Jovian brightness variations over yearly periods we determined $m(1, 0)$ for the three years separately. For each year, there was again fairly good agreement between sites when the dates of observation covered about the same period. The data from the two sites were thus combined. Corresponding values of $m(1, 0)$ and geometric albedo p for each year are given in Table II. The geometric albedo is computed from

$$\log_{10} p = 0.4[m_{\odot} - m(1, 0)] - 2 \log_{10} \sin \sigma_1', \tag{1}$$

Sagan et al. (eds.), Planetary Atmospheres, 349–352.

TABLE II
Spectral reflectivity of Jupiter for 1963–65

Filter	1963		1964		1965	
	$m(1, 0)$	p	$m(1, 0)$	p	$m(1, 0)$	p
v	−8.61 ±0.02	0.248	−8.71 ±0.03	0.270	−8.66 ±0.03	0.258
u	−8.81 ±0.01	0.297	−8.88 ±0.03	0.317	−8.93 ±0.02	0.330
s	−9.00 ±0.01	0.355	−8.98 ±0.03	0.348	−9.11 ±0.02	0.390
p	−9.08 ±0.01	0.382	−9.08 ±0.02	0.380	−9.20 ±0.02	0.423
m	−9.27 ±0.01	0.455	−9.24 ±0.02	0.442	−9.36 ±0.02	0.495
l	−9.35 ±0.01	0.487	−9.33 ±0.01	0.480	−9.43 ±0.02	0.526
k	−9.49 ±0.02	0.555	−9.47 ±0.01	0.547	−9.48 ±0.01	0.553
h	−9.31 ±0.01	0.470	−9.17 ±0.02	0.413	−9.13 ±0.02	0.398
g	−8.75 ±0.01	0.282	−8.86 ±0.01	0.312	−8.80 ±0.02	0.295
e	−8.83 ±0.02	0.303	−8.86 ±0.01	0.310	−8.78 ±0.02	0.289
U	−8.11 ±0.01	0.323	−8.03 ±0.02	0.301	−8.14 ±0.02	0.332
B	−8.55 ±0.01	0.427	−8.53 ±0.02	0.418	−8.63 ±0.02	0.458
V	−9.30 ±0.01	0.502	−9.38 ±0.02	0.502	−9.46 ±0.02	0.541

where $m_\odot$ and $\sigma'_1 = 95''.07$ were taken from Paper II. Figure 1 shows the spectra for each of the three years separately. We observe a brightening at the shorter wavelengths in 1965 relative to 1963 except for filter v (λ 3150). At longer wavelengths ($\lambda \geqslant 6264$ Å) the brightness is more nearly constant from year to year except in filter h (7297 Å). At this wavelength Jupiter is systematically brighter in 1963 relative to 1964 by 0.14 m and relative to 1965 by 0.18 m. There therefore appear to be real color changes in Jupiter over the three year period.

Our observations are consistent with and give further information on activity patterns of the planet Jupiter. According to Focas and Banos (1964) and a well accepted atmospheric model by Wasiutinsky (1946), turbulence in the Jovian atmosphere results in the appearance of dark matter which usually takes the form of dark blotches, filamentary strips, and veils. It is obvious that the appearance and disappearance of dark matter, if not black, will result in a color change of the planet. Focas and Banos (1964) and Aksenov *et al.* (1967) photographed Jupiter over the periods 1957 through 1963 and 1964 to early 1965, respectively, in order to measure intensity variations of the planet. They used an activity factor defined by Focas and Banos which is a measure of the amount of dark matter observed on the disk. The

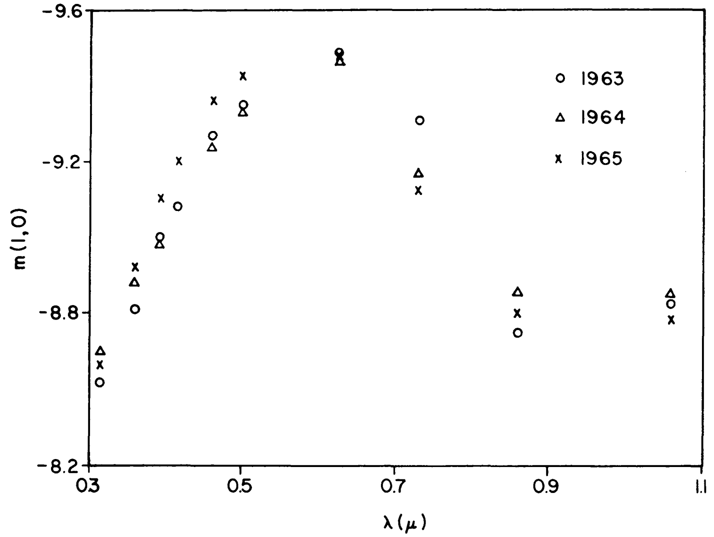

Fig. 1. Magnitudes $m(1, 0)$ of Jupiter at unit distance and zero phase for the years 1963–65.

amount of dark matter increased from 1961 to 1963 when the activity factor reached a maximum and our filter *h* appeared anomalous. There was then a decrease in activity until early 1965. According to Aksenov *et al.* it seems that Jupiter had returned in late 1965 to a 'quasi-normal' state. Note that solar activity was increasing in 1965 after being at a minimum in 1963–64. Khodyachikh as quoted by Aksenov *et al.* (1967) found no correlation between the Jovian activity factor and solar activity over a period from 1932 to 1959. However, Shapiro (1953) reports such a correlation in blue and yellow light for the period 1926–50.

The fraction of solar energy incident in the observed wavelength region and absorbed by the planet may be estimated from

$$p^* = \frac{\int_{\lambda_1}^{\lambda_2} \mathrm{d}\lambda p(\lambda) F(\lambda)}{\int_{\lambda_1}^{\lambda_2} \mathrm{d}\lambda F(\lambda)}, \tag{2}$$

where $\lambda_1 = 0.315\,\mu$, $\lambda_2 = 1.06\,\mu$, and $F(\lambda)$ is the solar spectrum (taken from Allen (1963)). We find

$$\begin{aligned} p^*\,(1963) &= 0.411, \\ p^*\,(1965) &= 0.427, \end{aligned} \tag{3}$$

so that there was an estimated change of 4% in the reflected radiation and a corresponding change of 3% in the absorbed radiation $(1 - p^*)$ in this wavelength interval (an accurate determination of the spherical albedo would require a knowledge of possible changes in the phase integral $q(\lambda)$). The observed change is quite small, particularly when compared with Low's (1969) observations of a change in thermal emission by a factor of 2.5 within the last few years.

We investigated the possibility of a correlation between the detailed variation in the magnitudes at 3590 Å, 5012 Å, 7297 Å, and 8595 Å and the longitude of the central meridian ω. Residuals with respect to the mean Jovian phase curves were determined using a linear least squares fit for each year of observation. The central meridian was determined from time of observations with filter h and the *American Epherimeris and Nautical Almanac* for both systems of rotation I and II (most of the dark matter seems to appear in the System II area). Plots of the residuals versus ω for each year show no obvious correlations. Similar analyses for time periods of one month also showed no effect. This suggests that activity was rather uniform with respect to longitude, or that fluctuations of the order of our observed residuals ($\lesssim \pm 0.08$ m) occur on a time scale short compared to a month. Since variations over periods of the order of two or three months and also daily fluctuations (Aksenov *et al.*, 1967) have been observed, our results are not surprising. No correlation was found with the position of the Great Red Spot.

Acknowledgments

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