TABLE I.

MICROMETER MEASURES OF DOUBLE STARS (continued)

ADS/DM	Name	α (1900) δ	Epoch -1900	θ	ρ	Est. mag.	No. Nights	Aperture
16649	β 79	23h 12m.5 - 2° 4'	61.550	33°.8	1".31	8.5 - 9.6	4	12
			61.593	33.0	1.47	8.4 - 9.6	4	36
16650	Hu 400	12.6 +17 46	61.656	163.4	0.28	7.0 - 8.2	4	36
16665	β 80	13.8 + 4 52	61.550	292.8	1.23	8.9 - 9.6	4	12
			61.593	293.4	1.17	8.8 - 9.6	4	36
16700	Hu 95	16.6 -12 50	61.645	4.1	0.26	10.4 - 10.9	4	36
16708	Hu 295	17.4 -15 36	61.555	78.8	0.24	5.7 - 6.3	4	36
16725	Σ 3008	18.6 - 9 0	61.562	175.2	4.12	7.3 - 8.1	4	12
			61.609	175.5	4.02	7.3 - 8.0	3	36
+19°5116	Wirtanen	26.7 +19 22	61.677	139.6	3.75	10.4 - 12.7	4	36
16819	Hu 298	27.1 + 6 32	61.618	274.0	0.17	7.5 - 7.7	4	36
16873	Fox 102	32.3 + 7 4	61.618	252.3	0.28	9.2 - 9.4	4	36
- 3°5723	φ 359	47.8 - 3 43	61.625	18.7	0.11	6.8 - 7.0	4	36
+ 0°5066	Rst 5491	48.4 + 1 8	61.590	53.0	1.13	8.4 - 11.4	5	36
17111	A 2100	51.7 + 4 10	61.566	226.1	0.34	7.2 - 8.0	3	36
17180	A 1249	57.3 +10 13	61.693	246.8	0.27	9.4 - 9.9	4	36
4	A 428	57.5 - 9 3	61.618	25.4	0.26	9.4 - 9.6	4	36

Notes:

10828 In *Astron. J.*, 63, 68, 1958, I have given a mean of four measures of ADS 10828. The first measure is not of this pair, but of the nearby pair ADS 10846. The result for 10828 should read: 1957.449, 22°.7, 0".24, 8.4–8.7, 3*n*.

11566 ADS identification corrected by Couteau to BD +31°3327. The separation of the faint pair CD seems to be increasing slowly, but the earlier measures made with smaller apertures may have been measured too small because of the pair's faintness. Companion *a* was seen by me, but not measured.

−6°4949 Slow increase in angle. Quadrant uncertain.

11954 ADS 11947, with erroneous identification and position, is identical with 11954.

11971 AB is certainly, BC probably optical.

12054 The separation is now only half that at discovery in 1902.

12145 The close pair is the north following component of the Struve pair, not the south preceeding as given in the ADS. Lettering altered correspondingly.

−11°5331 Slow retrograde motion.

−15°5665 Unchanged so far.

+2°4358 Very close, measures uncertain, but certainly changed since 1937. No other measures.

15267 Quadrant indeterminate.

15447 Too difficult for the 12-inch.

15963 AC C is optical.

+21°4772 Direct motion; separation decreasing.

−4°5728 The pair seems to have returned to the 1934 discovery position. Narrow apparent orbit.

16173 This pair will be very close during the next few years.

16189 Optical.

16190 Closing in; direct motion, very few measures.

16633 Narrow apparent orbit.

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The Color of the Moon

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Colors of 14 regions on the moon have been determined on the $B-V$ system. Small but significant color differences are found between some regions of the lunar surface. The maria exhibit a moderate range of colors, with Mare Tranquillitatis being the bluest. Compared to Mare Serenitatis the highlands of the southern hemisphere appear to be slightly reddish. The rayed craters Tycho and Copernicus do not show any color anomaly. Attention is drawn to a very dark blue region north of Schröter. The color index of Mare Serenitatis is found to be $B-V=+0.876\pm0.022$.

I. INTRODUCTION

Fifty years ago Wood (1910a, b; 1912) and Miethe and Seegert (1911) first drew attention to possible color differences among different regions of the moon. Extensive references to subsequent visual, photographic and spectrophotographic investigations are given by Minnaert (1961). Observers of the integrated color of the moon all agree that the moon is significantly redder than the sun. In particular, reference should be made to an investigation of the wavelength dependence of the lunar reflectivity by Stair and Johnston (1953). However, considerable difference of opinion exists with regard to the assignment of colors to different regions of the lunar surface. Minnaert has questioned the reality of the color differences found by Miethe and Seegert. Recently Harris (1961) has stated that "Observations of a number of areas on the moon give a mean $B-V$ color of $+0.92$ with little difference between the maria and the bright regions." In view of these uncertainties accurate photoelectric measurements of a representative sample of lunar formations appeared desirable.

II. INSTRUMENTATION

Observations of the moon were carried out with an unrefrigerated 1P21 phototube mounted at the Cassegrain focus of the David Dunlap Observatory 19-inch reflector. To prevent overloading of the phototube, a black cover containing four symmetrically placed holes, with a diameter of 2 inches each, was placed over the primary mirror during the lunar observations. The observations were made through focal plane diaphragms with diameters of 1.0 mm and 1.5 mm corresponding to 20″ and 30″ on the sky. The yellow observations were made through a Corning 3384 filter, the blue observations through Corning 5030 plus Shott GG13 filters. Observations of MK standards on six good nights gave the following relation between the instrumental and $B-V$ color systems:

$$C_{b-y} = -0.552 + 1.005\,(B-V) \qquad (1)$$
$$\pm 0.005 \pm 0.007.$$

The amplified output of the photomultiplier was fed to a Brown recorder. For the lunar observations the combined time constant of the amplifier and the recorder was less than 1 sec. A single color observation consisted of about 10 alternate yellow and blue deflections; each deflection lasting 10 sec. Two typical tracings are shown in Fig. 1. Since the 19-inch telescope is not provided with a lunar rate drive each observations represents a drift curve across a short strip of the lunar surface. From the deviations of individual observations from the mean of many observations it was found that the mean error of a single color observation of the maria is 0ᵐ011. The mean error of a color observation of terra, craters, and one dark spot was found to be 0ᵐ013.

TABLE I. Journal of observations.

Date 1961	$\Delta(B-V)$
1. M. Crisium	
Mar. 30/31	+0.007
June 26/27	+0.011
	+0.020
Sept. 17/18	+0.006
Oct. 20/21	+0.005
	−0.010
Oct. 21/22	+0.009
	−0.007
2. M. Fecunditatis	
Oct. 20/21	−0.009
Oct. 21/22	−0.007
	−0.012
3. M. Humorum	
Mar. 30/31	−0.010
June 26/27	−0.035
	−0.049
Oct. 20/21	−0.055
	−0.039
Oct. 21/22	−0.025
	−0.034
4. M. Imbrium	
Mar. 30/31	−0.009
June 26/27	−0.015
	−0.034
Oct. 20/21	+0.008
	−0.002
Oct. 21/22	0.000
	−0.022
5. M. Nectaris	
June 26/27	+0.005
Sept. 17/18	−0.021
Oct. 20/21	+0.009
	−0.007
Oct. 21/22	+0.001
	−0.010
6. M. Nubium	
Oct. 20/21	−0.016
Oct. 21/22	−0.028
	−0.032
8. M. Tranquillitatis	
June 26/27	−0.051
Sept. 17/18	−0.052
Oct. 20/21	−0.058
	−0.062
Oct. 21/22	−0.044
	−0.060
9. Wood's spot	
Mar. 30/31	+0.090:
June 26/27	−0.005
	+0.009
	+0.006
10. Dark spot *N* of Schröter	
June 26/27	−0.063
	−0.068
Oct. 20/21	−0.057
	−0.083
	−0.071
Oct. 21/22	−0.078
11. Terra *S* of M. Nectaris	
June 26/27	+0.021
	+0.007
Sept. 17/18	−0.006
Oct. 20/21	+0.032
	+0.013
Oct. 21/22	+0.009
	+0.002
12. Terra *S* of Tycho	
Mar. 30/31	+0.016
June 26/27	+0.025
	+0.020
Oct. 20/21	+0.026
Oct. 21/22	0.000
	+0.006
13. Copernicus	
Mar. 30/31	−0.005
June 26/27	+0.004
	+0.014
Oct. 20/21	+0.005
Oct. 21/22	+0.007
	+0.012
14. Tycho	
Mar. 30/31	−0.001
June 26/27	−0.056
	−0.021:
Oct. 20/21	−0.026
	+0.007
	−0.003
Oct. 21/22	−0.007
	−0.003

III. OBSERVATIONS

During the course of lunar observations the color of M. Serenitatis was observed after every two observations of other lunar formations. A smooth curve giving the color of Mare Serenitatis as a function of hour angle was drawn through the individual observations. This curve was then used to determine the color difference between Mare Serenitatis and other lunar features. The sign of the color difference $\Delta(B-V)$ will be defined by the equation

$$\Delta(B-V) = (B-V) - (B-V)_0, \qquad (2)$$

in which $(B-V)_0$ is the color index of Mare Serenitatis. The individual observations of $\Delta(B-V)$ are listed in Table I. Table II gives the mean values of $\Delta(B-V)$ for a number of lunar regions, which are identified on the plate. n is the number of observations on which each mean color difference is based. Inspection of the data in Table II shows that some small but significant color differences exist between different lunar formations (the

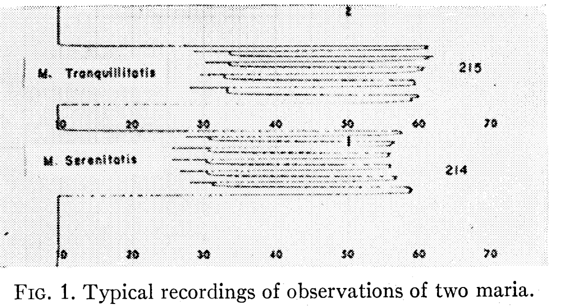

FIG. 1. Typical recordings of observations of two maria.

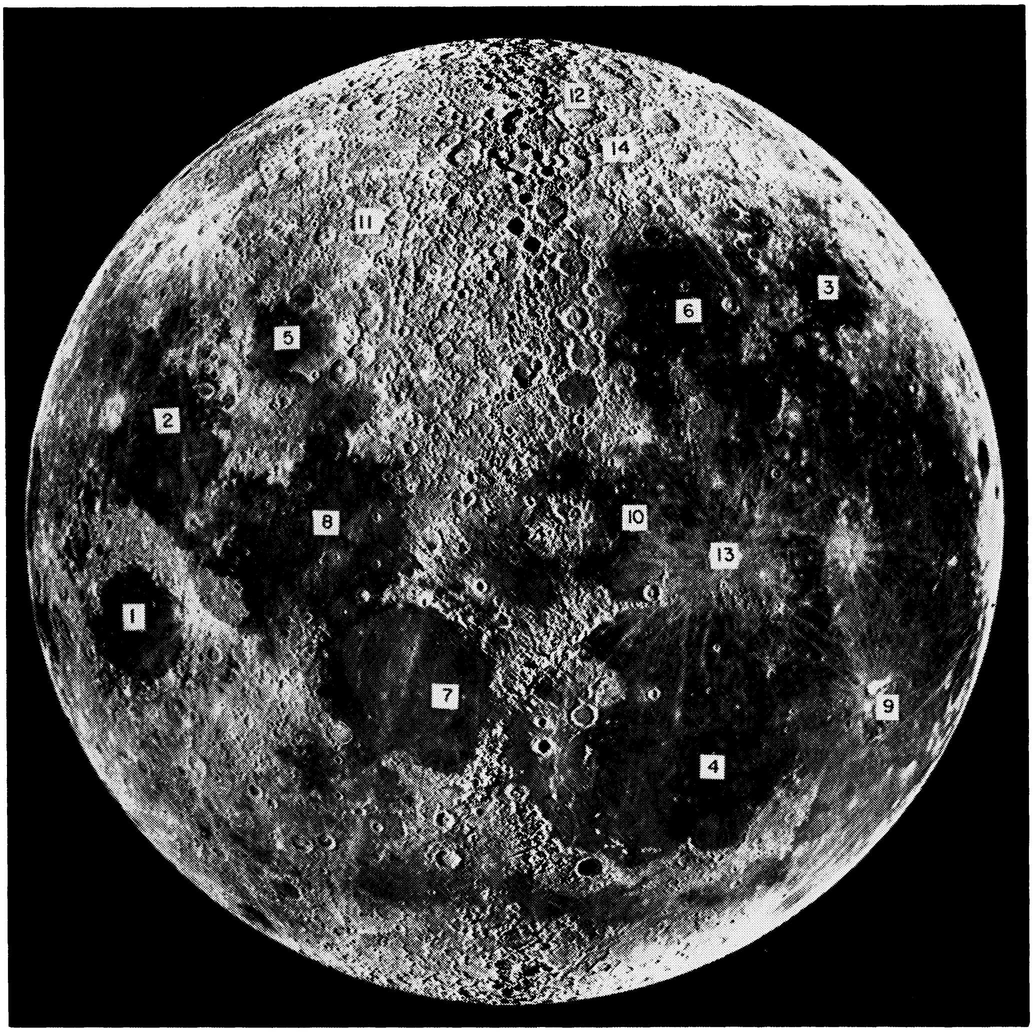

PLATE I. Identification map showing the exact positions to which the color measurements of lunar formations refer. Lick Observatory photograph.

present data, which were mostly taken close to full moon, are not suitable for an investigation of possible phase dependent color effects.) The range of colors exhibited by the maria are of particular interest. Mare Serenitatis is located near the red end of the color spectrum and Mare Tranquillitatis is by far the bluest of the maria. The differences between the floors of Mare Serenitatis and Mare Tranquillitatis is also apparent on lunar photographs. Such photographs (Wright 1929) show that a sharp boundary exists between the dark floor of Mare Tranquillitatis and the brighter floor of Mare Serenitatis; the difference being more pronounced in the red than in the ultraviolet. The rather scanty data on the lunar highlands appear to indicate that they are possibly slightly redder than Mare Serenitatis. The rayed craters Tycho and Copernicus do not seem to exhibit any marked color anomaly.

The region northeast of Aristarchus (Wood's spot), which was reported to be very dark in the ultraviolet by Wood, exhibits greater brightness variations over small distances than any other area of the moon. Due to the lack of a lunar rate drive on the telescope it proved impossible to measure the color of this region accurately.

TABLE II. Mean color differences of lunar formations.

Region	$\overline{\Delta(B-V)}$	m.e.	n
1. M. Crisium	$+0.005\pm0.004$		8
2. M. Fecunditatis	-0.009 ± 0.006		3
3. M. Humorum	-0.035 ± 0.004		7
4. M. Imbrium	-0.011 ± 0.004		7
5. M. Nectaris	-0.004 ± 0.004		6
6. M. Nubium	-0.025 ± 0.006		3
7. M. Serenitatis	0.000 standard		
8. M. Tranquillitatis	-0.054 ± 0.006		6
9. Wood's spot	$+0.003$[a]		3
10. Dark spot *N* of Schröter	-0.070 ± 0.005		6
11. Terra *S* of M. Nectaris	$+0.011\pm0.005$		7
12. Terra *S* of Tycho	$+0.016\pm0.005$		6
13. Copernicus	$+0.006\pm0.005$		6
14. Tycho	-0.014 ± 0.005		8

[a] One discordant observation rejected.

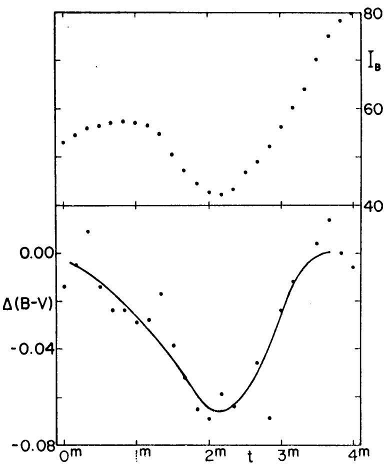

FIG. 2. Color (lower panel) and blue intensity (upper panel) scan across the dark area north of Schröter produced by lunar motion during a 4 minute interval. The scan shows that the darkest and bluest areas coincide.

The area north of the crater Schröter is one of the darkest regions of the full moon. Photographs of this region appear to indicate that the rays of the Copernicus system stop abruptly at the edges of this area. Possibly this indicates that the area is composed of hard formations which were not scarred by the explosive event which gave rise to the crater Copernicus. Alternatively it might be assumed that the area north of Schröter was formed later than the rays emanating from Copernicus. In any event, it is interesting that this region is bluer than any other lunar formation measured in the course of the present program. A color and intensity drift curve across this area is shown in Fig. 2.

On the whole, the present photoelectric color observations substantiate the reality of the features shown on the color map of the moon published by Miethe and Seegert in 1911. It is of particular interest to note that these authors found the dark spot north of Schröter to be the bluest region of the lunar surface. The color map of Miethe and Seegert also clearly shows the sharp color discontinuity at the boundary between M. Tranquillitatis and M. Serenitatis.

TABLE III. Color measurements of Mare Serenitatis.

Date	$(B-V)_0$
October 7/8 1960	+0.893
March 30/31 1961	+0.855
June 26/27 1961	+0.882
October 20/21 1961	+0.854
October 21/22 1961	+0.897
Adopted mean	+0.876 ±0.022

IV. COLOR OF MARE SERENITATIS

The color measurements of Mare Serenitatis were tied into the $B-V$ system on five nights. The individual observations are given in Table III. The quoted mean error of the color of Mare Serenitatis includes the uncertainties in the instrumental color equation. However, it does not take into account the possibility that small differences exist between the color equation of the entire mirror and the color equation of the small regions of the mirror which were used during the lunar measurements.

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