SPECTRAL REFLECTANCE CURVES OF THE PLANET MERCURY

by

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(1973)

Submitted in partial fulfillment

of the requirements for the degree of

Master of Science in Earth and Planetary Science

at the

Massachusetts Institute of Technology
September 1975

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Earth and Planetary Sciences

ABSTRACT

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Submitted to the Department of Earth and Planetary Science on June 13, 1975 in partial fulfillment of the requirements for the degree of Master of Science in Earth and Planetary Science.

A large-scale program to determine the surface composition of the planet Mercury was begun in September 1974. Observations of Mercury have been made around elongations of October 1, 1974, January 23, 1975, and March 6, 1975 at the Cerro Tololo Interamerican Observatory, La Serena, Chile. A dual-beam filter photometer was used with a set of 24 narrow-band interference filters of wavelengths from 0.3250-1.066μm. Reflection spectra from the preliminary data reduction show uniform strong blue and ultraviolet absorption suggesting a surface composed of dark glasses containing iron and titanium. These spectra are similar to reflection spectra for lunar mare and uplands regions.

Thesis Supervisor: Thomas B. McCord

Title: Associate Professor of Planetary Physics

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PROFESSOR THOMAS B. McCORD FOR PROVIDING ME WITH THE OPPORTUNITY TO DO THIS WORK.
AND THE MEMBERS OF THE MIT CENTER FOR REMOTE SENSING for ADVICE AND ASSISTANCE GIVEN TO ME OVER THE PAST TWO YEARS.
ACKNOWLEDGEMENTS
I WOULD LIKE TO THANK...
MR. DOUGLAS J. MINK FOR WRITING THE MERCURY EPHEMERIDES PROGRAM
AURA, INC. TRAVEL...
FOR ASSISTANCE TO CHILE TO MAKE THESE OBSERVATIONS.
COOLIDGE BANK & TRUST CO. SAVINGS ACCOUNT #05-1499 & CHECKING ACCOUNT #435-841-4 FOR... ALL THE SUPPORT THEY HAVE GIVEN ME DURING THE PAST TWO YEARS.
285
FAITH VILAS
PAY TO THE ORDER OF
Vilas
435-841
ALL MY FRIENDS WHO HAVE ENCOURAGED (& BROW-BEATEN) ME TO FINISH THIS DEGREE.
if you leave now, you will NEVER GO BACK.
SICK 'EM VILAS.

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I. Introduction

Mercury has traditionally been a difficult planet to observe with ground-based optical equipment due to its small elongation angle; observers risk interference with the sun. Comparatively few studies of Mercury have been attempted until the Mariner 10 spacecraft mission. No extensive study of the spectral reflectance (diffuse reflected solar radiation from the surface of a solar system object) of Mercury has been conducted, although it has been measured by three different observers in the past.

McCord and Adams (6,7) have previously made spectral reflectance curves for Mercury from data obtained on two different nights of observations. The first data set was taken on December 25, 1969 using the 60-inch telescope at the Cerro Tololo Interamerican Observatory, La Serena, Chile; the second data set was taken on March 12, 1972 using the 36-inch #2 telescope at the Kitt Peak National Observatory, Kitt Peak, Arizona. Both sets of observations were taken through 22 narrow-band interference filters spaced evenly across the 0.32 - 1.05 μm region of the spectrum. Figure I (7) shows these curves along with the spectral reflectance values of the disk of Mercury made by Harris (4)

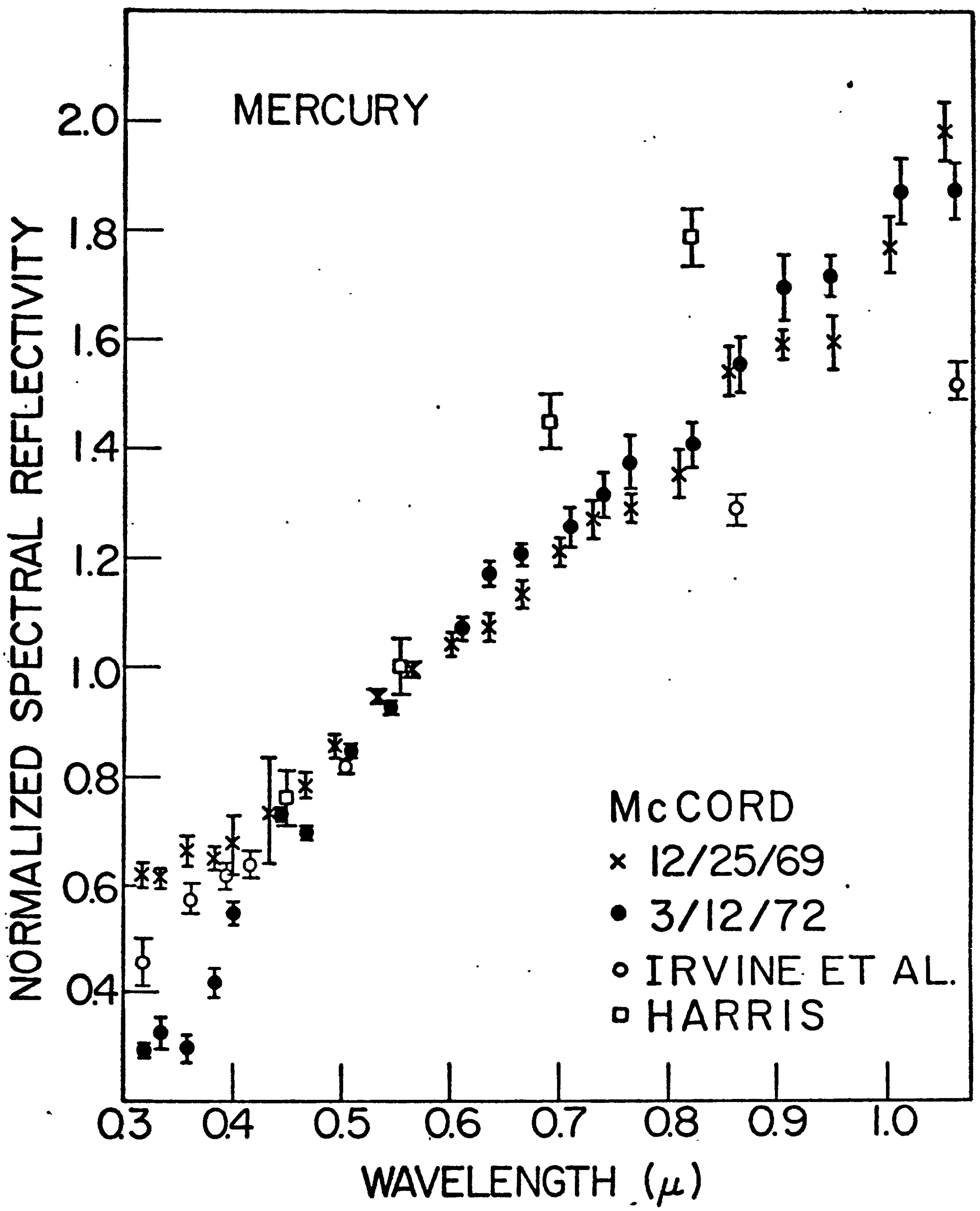


Figure I. Mercury Spectral Reflectance
McCord and Adams (7)

and Irvine (5). All four curves show an increase in reflectance with wavelength, but the slope varies with each of the four observations. Only McCord and Adams' curves have enough resolution to show absorption features in the spectra. A comparison of these two curves with recent data curves and interpretations will be presented in more detail.

A large-scale study of Mercury to make a series of observations of the planet on a day-by-day basis around elongations was begun in September 1974. By taking advantage of both Mercury's crescent phases near an elongation and its slow rate of rotation (approximately 5° per day), some spatial resolution of the planet can be obtained. If variations in the spectra are observed over a period of days, one can assign spectral variations to variations in the mineralogical composition of the planet's surface. Correlation of the spectra with surface features photographed in the recent Mariner 10 mission may then be possible.

At this time, Mercury has been observed around elongations of October 1, 1974, January 23, 1975, and March 6, 1975. A description of the observing runs and data reduction procedures will be followed by preliminary interpretations of the data curves.

II. Observations

Mercury was observed near the elongations on October 1, 1974 (26°W), January 23, 1975 (19°W), and March 6, 1975 (27°E) on the 36-inch telescope at the Cerro Tololo Inter-american Observatory, La Serena, Chile. A dual-beam photometer was used with an ITT fw-118 photomultiplier tube with an S-1 photocathode. The photoelectron pulses were amplified, counted, and stored on magnetic tape by a data collection system. The photometer chopped at 10 H_z between the visible portion of the planet's disk and a portion of the sky near the planet with 39 chops per filter, so that a total number of photons for the planet and background sky was recorded for each filter. Photon counts taken through all 24 filters in a set comprise one observation. Except for one day, all of the observations used the Spectrum 25B filter set consisting of 24 narrow-band filters ranging in wavelength from 0.32 - 1.066 μm at intervals of approximately 0.3 μm . On September 30, 1974, the Wallace filter set with 24 narrow-band filters ranging from 0.3306 - 1.063 μm at intervals of approximately 0.3 μm was used. The aperture used to view the planet was approximately 1.5 mm in diameter. Special effort was made to eliminate as much scattered light from the photometer as possible. Observations were made on 10 afternoons in September and October of 1974, 3 afternoons in January 1975, and 5 mornings in March 1975. Table I lists the dates of observations, Mercury's celestial coordinates, standard stars used for extinction corrections, number of observations of Mercury and the stars, the phase of Mercury, and a statement on the sky conditions for those observations.

Observations with the dark slide closed were made so that one could determine if any signal was produced by the tube itself. Cooling with dry ice reduced this signal to a few counts per second, a level which will have negligible effect on planet and star counts so that no corrections must be made for this signal in the data reduction. Observations of sky brightness were taken in both beams to determine whether one beam consistently received a larger amount of light than the other when the same light source was used for both beams. Finally, scattered light observations (a metal slug is substituted for the aperture and any count recorded is from extra light present in the photometer) were also made. Sky/sky and scattered light observations are particularly important when observing Mercury since the planet is observed at either dawn or dusk and the background sky light is great compared to that of a dark night. If a greater amount of light was entering one beam than the other, it will have an appreciably greater effect on the observations when the background sky is so bright. Scattered light counts can be much higher because more light can get into the photometer.

During the September/October observing run, the two mirrors on the chopper in the photometer were not phase-positioned correctly. This caused a portion of the background sky count to be added into the object count, although none of the object count was added into the background sky count. The mirrors were temporarily repositioned near the end of the run, and centered correctly before the beginning of the January run.

The elongation of January 23, 1975 (19°W) was too small a separation to effectively observe Mercury. In order to obtain Mercury at sufficiently low airmass, it was necessary to make observations during the late afternoon while the sun was still visible. Consequently, the counts for object and background sky were extremely high, approaching, if not exceeding, the counting limit of the data system. This may have resulted in a distorted value of the actual count, or in the count exceeding the limit and "wrapping around" so that an inaccurate figure for the total photon count of the object or background sky was recorded. A procedure for determining the true data counts is being developed. Future observations of Mercury probably should be made around the

Table I. Mercury Observations

Date	Mercury α	Mercury δ	Standard Star(s)	No. of Runs of Mercury
27 Sep 74	13^h43^m	$-13^\circ13'$	109 VIR	8
28 Sep 74	13 48	-13 44	109 VIR,A LYR	8
29 Sep 74	13 52	-14 16	109 VIR,A LYR	8
30 Sep 74	13 55	-14 42	109 VIR,A LYR	6
1 Oct 74	13 59	-15 09	109 VIR,A LYR	10
4 Oct 74	14 10	-16 24	109 VIR,A LYR	7
5 Oct 74	14 13	-16 42	109 VIR,A LYR	9
6 Oct 74	14 16	-17 02	109 VIR,A LYR	14
7 Oct 74	14 19	-17 20	A LYR	14
8 Oct 74	14 21	-17 33	A LYR	12
28 Jan 75	21 48	-12 20	A PSA	22
29 Jan 75	21 48	-11 54	A PSA	16
31 Jan 75	21 48	-11 18	G PSC	10
7 Mar 75	21 27	-15 41	E AQR	8
8 Mar 75	21 31	-15 36	E AQR	11
9 Mar 75	21 35	-15 24	E AQR	13
10 Mar 75	21 40	-15 09	E AQR	16
11 Mar 75	21 45	-14 53	E AQR	16

Table I con't.

Date	No. of Runs of Star(s)	Approximate Phase	Sky Conditions
27 Sep 74	11	.667	Good seeing
28 Sep 74	12,11	.653	Bad seeing, clouds
29 Sep 74	5,5	.638	Seeing OK
30 Sep 74	6,3	.624	Hazy,mottled clouds
1 Oct 74	9,7	.606	Good seeing
4 Oct 74	7,7	.550	Some haze
5 Oct 74	4,6	.532	Clear,slight haze
6 Oct 74	4,10	.508	Clear,slight haze
7 Oct 74	15	.484	Good seeing
8 Oct 74	9	.459	Seeing ok
28 Jan 75	19	.363	Hazy
29 Jan 75	17	.3]8	Hazy,some clouds
31 Jan 75	10	.227	Cloudy,marginal
7 Mar 75	7	.578	Clear, good seeing
8 Mar 75	11	.593	Clear, good seeing
9 Mar 75	17	.609	Clear, good seeing
10 Mar 75	12	.622	Clear, good seeing
11 Mar 75	20	.635	Clear, good seeing

larger elongations of approximately 25° separation.

After the first day of the March observing run, the telescope was moved to the opposite side of the mount which enabled the planet and standard star to be picked up closer to the horizon when the sky was darker, allowing greater airmass coverage.

While the observations made during these three runs will add considerably to present information on the spectral reflectance of Mercury, it is recommended that the series of observations around elongations be continued.

III. Data Reduction

Reduction of data followed essentially the same format for the three observing runs (Figure II), with the exception of correcting for the portion of the background sky beam added to the object beam in the September/October run. The data was run through a series of computer programs developed at the MIT Center for Remote Sensing for photometer data reduction. First, the data from the original magnetic tape was fed into a program which prints out both the photon count for the planet and photon count for the background sky for each of the 24 filters in one observation. The program then computes the counts/second for the background sky and the planet. If desired, the background sky count can then be subtracted from the object count leaving a value for the object alone in counts/second. Data from the January and March runs was put into this mode. Background sky counts were not subtracted from object counts for the September/October run in order to make further corrections for beam addition. Dark counts, sky/sky counts, and scattered light counts were examined here to see if any corrections were needed in the data reduction. No corrections were necessary for the January and March observations. Scattered light and dark counts were sufficiently low so that they had no effect on the September/October run, but it was necessary to correct for the portion of the background sky beam in the object beam.

To determine a constant correction factor for the beam addition in the September/October data, a few observations were made with a bright star (both Alpha Lyrae and Alpha Aquarius were used) which was centered in the mirror normally used for the background sky beam. Background sky was recorded in the mirror normally used for the object beam. For each of the 24 filters in one observation a ratio of background sky count/star count was computed, and an average was taken of all 24 ratios. An overall average for the set of observations was then computed. During the first part of the September/October run, this factor had a value of 0.037. After the mirrors were temporarily repositioned, this value was 0.010 . All of the background sky counts were then multiplied by the appropriate value of this factor. The resulting fractions of the background sky counts were equivalent to the portions of the background sky beam added into the object beam; they were then subtracted from the corresponding object counts. After that, the total background sky counts were subtracted from the object counts leaving counts for the planet alone. Corrections for beam additions were only necessary for data affecting Mercury since background sky counts were not high enough to affect observations made during the night.

A second program inputs the intensity in counts/second and additional information for all observations of one object during one day. For each of the 24 filters, the program outputs 24 graphs of airmass plotted against the natural logarithm of the intensity for all observations made through the same filter. A least squares fit of the points is drawn on the graph. The output also provides a graph of wavelength against the slopes of the least squares fit lines, and a graph of wavelength against the natural logarithm of the intensity at one airmass (from extrapolation of the least squares fit). These slope and intercept values are the calculated atmospheric extinction coefficients and intensity values used when determining the intensity of the object at a given sky location from the formula:

$$I = I_o - e^{-\tau x}$$

I_o = intensity at one airmass

τ = extinction coefficient (1/airmass) (dependent on sky conditions)

x = number of airmasses through which observation is made

I = the intensity at the given airmass

At this point, the data for both Mercury and the standard stars were imput into this program and examined for anomalous values. Criteria were established to determine which points should be deleted. In general, data points with deviations of greater than 2-3% from the least squares fit were deleted, up to a maximum of 40% of the points for one filter. When a few erratic points caused the fit to be obviously wrong, those points were deleted allowing a new fit to be made to the points. In the ultraviolet filters occasionally more than 40% of the data deviated from the least squares fit by greater than 2-3%. Points were then deleted to get the best possible fit among the data regardless of the data spread.

After deleting anomalous data points, the observations for objects used to make extinction curves were again input into the second program creating more accurate coefficient and intercept values. Standard stars were used for both the January and March observing runs. In the September/October run, standard stars were used unless too few star observations had been made. Mercury values were then used to make extinction curves. This data was stored on disk for use in a third program.

Observations for Mercury (and, where used, standard stars) were input into a third program after the deletion of anomalous points. This program ratioed the intensity values of one observation of Mercury at a given airmass against intensity values at the same airmass (as derived from the extinction formula) for the standard star observed on the same day. Values of Mercury/star were scaled to 1.000000 for the 0.5660μm filter. Average values and standard deviations for all of the observations during one night were then computed. The standard star/Mercury ratios computed in the third program were then inverted to get the desired Mercury/star ratios.

Since Mercury/sun reflectance values are the desired final product, these Mercury/star ratios needed to be multiplied by various star/star and star/sun ratios. These ratios (Tables II-A,B,C,D) are intermediate values from an ongoing standard star calibration program being conducted by the MIT Center for Remote Sensing. The September/October run required 109 VIR/A LYR and A LYR/SUN for both the Spectrum 25B and Wallace filter sets. A PSA/A AQR, A AQR/A LYR, and A LYR/SUN ratios for the Spectrum 25B set were used for the January run. E AQR/A LYR and A LYR/SUN for the Spectrum 25B set were used in March. A fourth program multiplied the Mercury/star ratios to get the Mercury spectral reflectance values and their computed errors (Tables III-A,B,C,D,E,F,G,H, I,J; Tables IV-A,B; Tables V-A,B,C,D,E). Curves of spectral reflectance plotted against wavelength also were made for each day of observations (Figures III-A,B,C,D,E,F,G,H,I,J; Figures IV-A,B; Figures V-A,B,C,D,E).

Figure II. Flowchart of Data Reduction Procedures

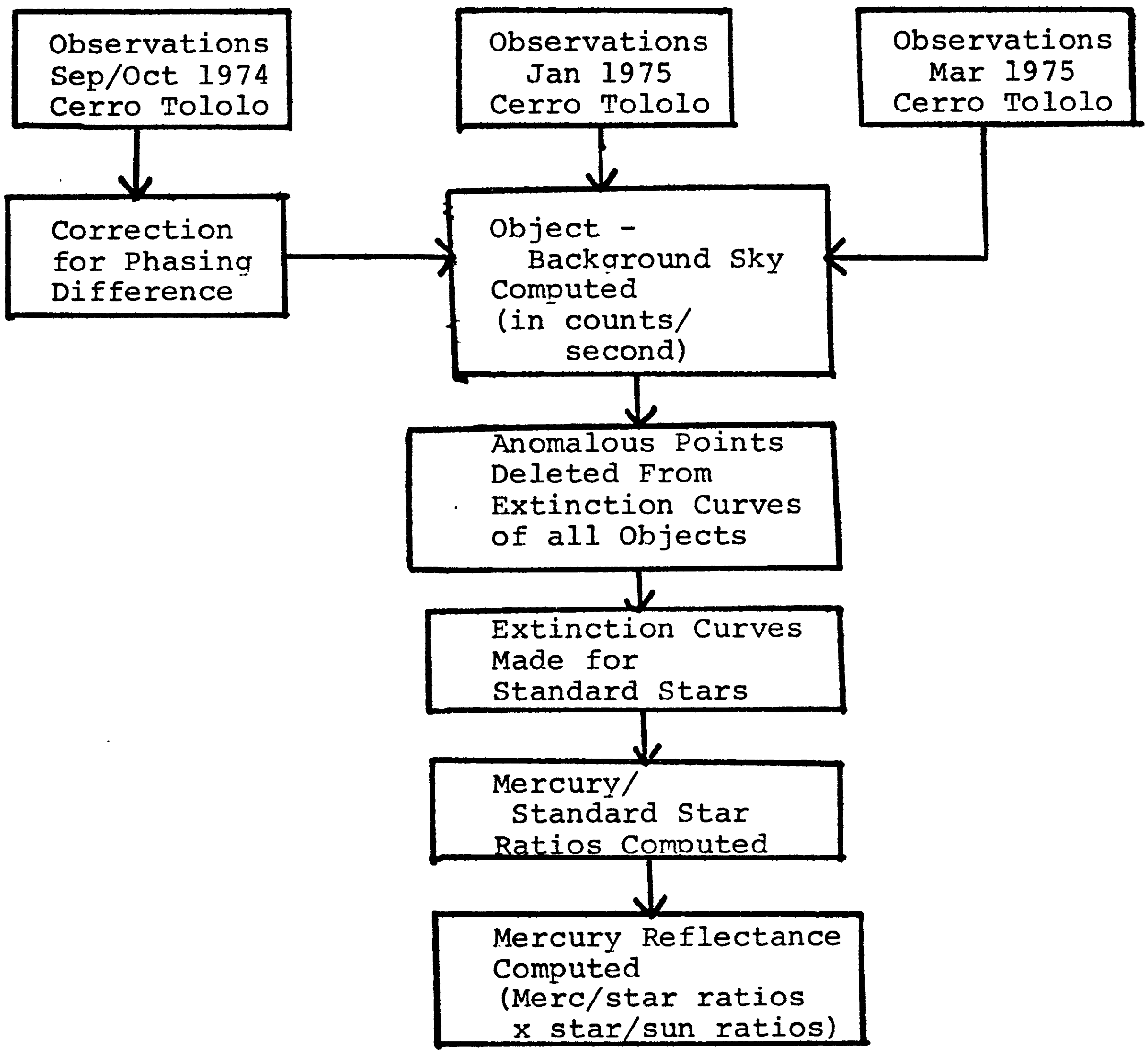


TABLE II - A. STAR RATIOS

SPECTRUM FILTERS - SEPTEMBER/OCTOBER 1974

Wavelength (μm)	109 VIR/ A LYR	Error	Calibrated A LYR/SUN	Error
0.3250	1.187949	0.016120	2.030000	0.00
0.3500	1.162718	0.007386	1.834000	0.00
0.3750	1.170385	0.017454	2.433000	0.00
0.4000	1.117105	0.015360	2.566000	0.00
0.4330	1.069974	01006644	2.115000	0.00
0.4660	1.034109	0.001995	1.558000	0.00
0.5000	1.027095	0.002658	1.325000	0.00
0.5330	1.005957	0.005815	1.153000	0.00
0.5660	1.000000	0.000712	1.000000	0.00
0.6000	1.018673	0.000688	0.858000	0.00
0.6330	1.027330	0.003802	0.789000	0.00
0.6660	1.016684	0.001338	0.685000	0.00
0.7000	1.017797	0.006546	0.665000	0.00
0.7330	1.027622	0.000427	0.622000	0.00
0.7660	1.024835	0.003659	0.590000	0.00
0.8000	1.005291	0.006607	0.555000	0.00
0.8330	1.011586	0.001150	0.536000	0.00
0.8660	1.014871	0.001610	0.533000	0.00
0.9000	1.043891	0.001558	0.525000	0.00
0.9330	1.095496	0.010480	0.519000	0.00
0.9660	1.044887	0.006657	0.509000	0.00
1.0000	0.987037	0.010137	0.468000	0.00
1.0330	0.983893	0.006428	0.469000	0.00
1.0660	0.965581	0.007670	0.457000	0.00

TABLE II - B. STAR RATIOS

WALLACE FILTERS - SEPTEMBER 30, 1974

Wavelength (μm)	109 VIR/ A LYR	Error	Calibrated A LYR/SUN	Error
0.3306	0.805964	0.014978	2.072700	0.00
0.3428	0.896980	0.011608	1.905000	0.00
0.3812	0.898035	0.014526	2.862100	0.00
0.4037	0.932897	0.011061	2.623600	0.00
0.4370	0.957465	0.007023	1.997200	0.00
0.4716	0.962310	0.008526	1.499400	0.00
0.5033	1.006330	0.004035	1.317500	0.00
0.5383	0.991881	0.004117	1.137600	0.00
0.5659	1.000000	0.005984	1.000000	0.00
0.6050	1.044109	0.003351	0.848900	0.00
0.6376	1.065961	0.006632	0.769000	0.00
0.6696	1.054908	0.004068	0.683400	0.00
0.7010	1.068935	0.005650	0.652200	0.00
0.7348	1.055387	0.007976	0.617400	0.00
0.7685	1.037148	0.006329	0.581200	0.00
0.8006	1.072942	0.015887	0.551400	0.00
0.8348	1.098969	0.007394	0.525400	0.00
0.8679	1.152732	0.005543	0.555500	0.00
0.9020	1.103662	0.005829	0.540200	0.00
0.9336	1.061151	0.016038	0.490700	0.00
0.9667	1.077783	0.010201	0.507600	0.00
0.9988	1.122651	0.012719	0.476200	0.00
1.0340	1.139194	0.020326	0.467200	0.00
1.0630	1.056647	0.037557	0.439900	0.00

TABLE II - C. STAR RATIOS

SPECTRUM FILTERS - JANUARY 1975

Wavelength (μm)	A PSA/A AQR	Error
0.3250	3.549290	0.022446
0.3500	3.092580	0.018005
0.3750	3.513459	0.023132
0.4000	3.768240	0.022178
0.4330	2.585959	0.031608
0.4660	1.757239	0.002774
0.5000	1.418340	0.006403
0.5330	1.166430	0.006760
0.5660	1.000000	0.005409
0.6000	0.850715	0.005259
0.6300	0.792602	0.004587
0.6660	0.681732	0.003111
0.7000	0.652621	0.005502
0.7330	0.607890	0.004734
0.7660	0.562788	0.004914
0.8000	0.530961	0.002145
0.8330	0.512170	0.002550
0.8660	0.492822	0.001751
0.9000	0.471321	0.003305
0.9330	0.475815	0.004313
0.9660	0.462791	0.004907
1.0000	0.426351	0.002413
1.0330	0.424700	0.002635
1.0660	0.410801	0.002732

TABLE II - C. (CONT'D.)

Wavelength (μm)	A AQR/ A LYR	Error	Calibrated A LYR/SUN	Error
0.3250	0.143251	0.001432	2.030000	0.00
0.3500	0.199176	0.001296	1.834000	0.00
0.3750	0.190441	0.000498	2.433000	0.00
0.4000	0.198091	0.000755	2.566000	0.00
0.4330	0.333355	0.001236	2.115000	0.00
0.4660	0.515052	0.002105	1.558000	0.00
0.5000	0.666650	0.000582	1.325000	0.00
0.5330	0.816445	0.001792	1.153000	0.00
0.5660	1.000000	0.002006	1.000000	0.00
0.6000	1.199527	0.002474	0.858000	0.00
0.6330	1.306247	0.001549	0.789000	0.00
0.6660	1.546218	0.002967	0.685000	0.00
0.7000	1.614037	0.005998	0.665000	0.00
0.7330	1.760685	0.003718	0.622000	0.00
0.7660	1.929747	0.004112	0.590000	0.00
0.8000	2.051161	0.003480	0.555000	0.00
0.8330	2.185134	0.009346	0.536000	0.00
0.8660	2.245746	0.005587	0.533000	0.00
0.9000	2.337281	0.010713	0.525000	0.00
0.9330	2.281334	0.014056	0.519000	0.00
0.9660	2.419450	0.016039	0.509000	0.00
1.0000	2.655968	0.010005	0.468000	0.00
1.0330	2.648720	0.013174	0.469000	0.00
1.0660	2.748358	0.009954	0.457000	0.00

TABLE II - D. STAR RATIOS

SPECTRUM FILTERS - MARCH 1975

Wavelength (μm)	E AQR/ A LYR	Error	Calibrated A LRY/SUN	Error
0.3250	0.872000	0.023982	2.030000	0.00
0.3500	0.864326	0.009228	1.834000	0.00
0.3750	0.872141	0.008209	2.433000	0.00
0.4000	1.006445	0.005392	2.566000	0.00
0.4330	0.983261	0.002856	2.115000	0.00
0.4660	1.004646	0.005849	1.558000	0.00
0.5000	1.012012	0.003555	1.325000	0.00
0.5330	0.995035	0.002664	1.153000	0.00
0.5660	1.000000	0.004948	1.000000	0.00
0.6000	0.982383	0.004543	0.858000	0.00
0.6330	0.973632	0.005043	0.789000	0.00
0.6660	0.989285	0.004028	0.685000	0.00
0.7000	0.985797	0.006233	0.665000	0.00
0.7330	1.009096	0.004941	0.662000	0.00
0.7660	1.011564	0.006979	0.590000	0.00
0.8000	1.011974	0.008143	0.555000	0.00
0.8330	1.005286	0.008372	0.536000	0.00
0.8660	1.009491	0.013580	0.533000	0.00
0.9000	1.023870	0.007546	0.525000	0.00
0.9330	1.006918	0.009459	0.519000	0.00
0.9660	1.009392	0.008546	0.509000	0.00
1.0000	1.002746	0.009619	0.468000	0.00
1.0330	0.985709	0.011106	0.469000	0.00
1.0660	0.956441	0.013786	0.457000	0.00

TABLE III - A. MERCURY REFLECTANCE

SEPTEMBER 27, 1974

(109 VIR)

Wavelength (μm)	Reflectance	Error
0.3250	0.672127	0.044069
0.3500	0.666997	0.023385
0.3750	0.687677	0.051208
0.4000	0.721105	0.044599
0.4330	0.771192	0.018163
0.4660	0.840802	0.010080
0.5000	0.903527	0.009726
0.5330	0.968211	0.013696
0.5660	1.000000	0.006773
0.6000	1.075491	0.007501
0.6330	1.122299	0.007975
0.6660	1.143381	0.010251
0.7000	1.229207	0.015508
0.7330	1.258995	0.011232
0.7660	1.330896	0.015528
0.8000	1.354741	0.007204
0.8330	1.411528	0.007530
0.8660	1.448984	0.012254
0.9000	1.559191	0.020798
0.9330	1.682184	0.009095
0.9660	1.584104	0.020836
1.0000	1.555896	0.010603
1.0330	1.602626	0.034898
1.0660	1.665401	0.016660

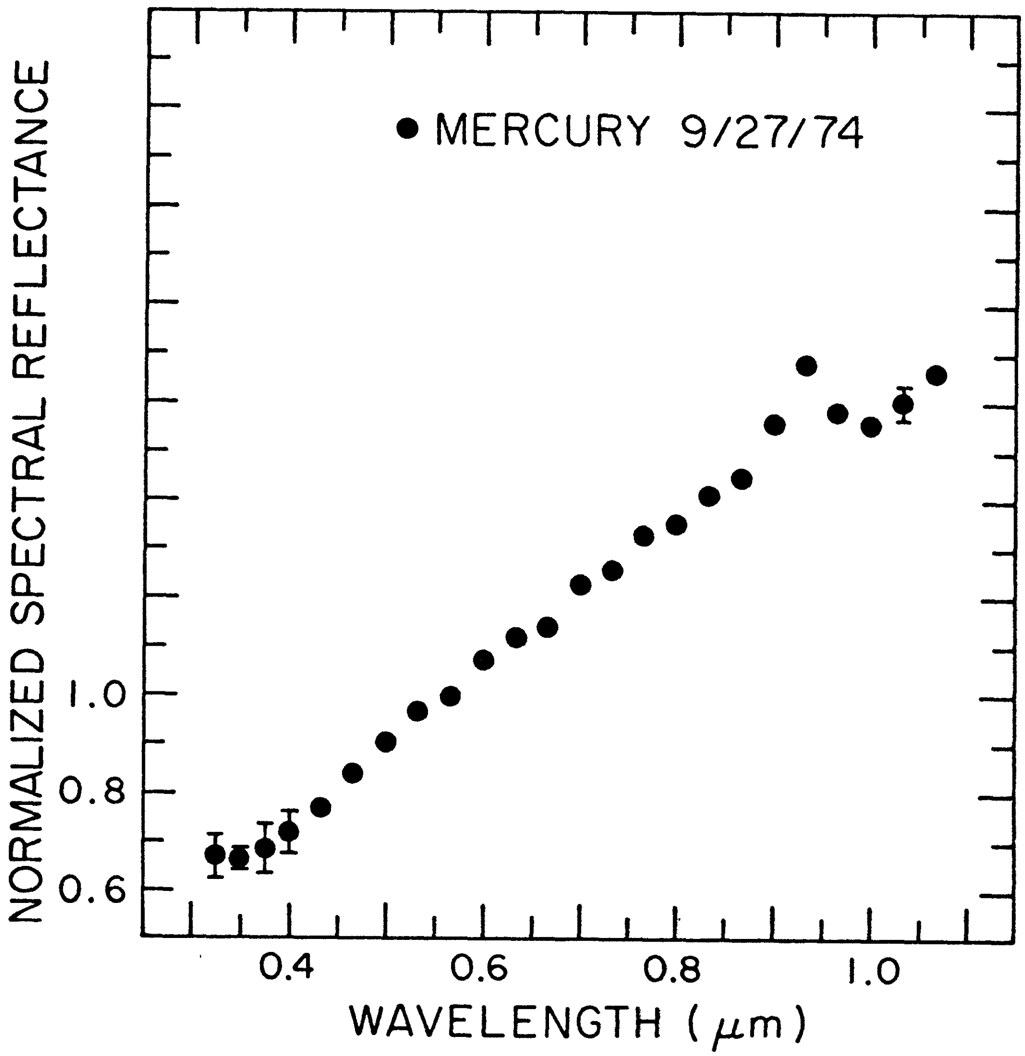


Figure III-A. Mercury Reflectance September 27,1974
(109 VIR)

TABLE III - B. MERCURY REFLECTANCE

SEPTEMBER 28, 1974

	(A LYR)		(109 VIR)	
Wavelength (μm)	Reflectance	Error	Reflectance	Error
0.3250	0.583563	0.021191	0.627697	0.040099
0.3500	0.674404	0.083518	0.651772	0.031285
0.3750	0.679649	0.028999	0.696162	0.051552
0.4000	0.650108	0.012496	0.712348	0.044455
0.4330	0.753619	0.040951	0.774141	0.019750
0.4660	0.818046	0.017682	0.848825	0.008229
0.5000	0.859887	0.014221	0.890500	0.007263
0.5330	0.900469	0.012210	0.964446	0.008343
0.5660	1.000000	0.008762	1.000000	0.003702
0.6000	0.973241	0.005828	1.036321	0.009739
0.6330	0.896982	0.048612	1.088339	0.007709
0.6660	1.081587	0.016011	1.086296	0.009137
0.7000	1.011485	0.073463	1.183870	0.013719
0.7330	1.053302	0.030548	1.199936	0.010325
0.7660	1.051433	0.097130	1.232285	0.023466
0.8000	1.103066	0.078752	1.310631	0.008695
0.8330	1.239095	0.040673	1.347974	0.019972
0.8660	1.330932	0.032814	1.380385	0.027050
0.9000	1.189621	0.068983	1.459444	0.012265
0.9330	1.397110	0.093076	1.541960	0.032952
0.9660	1.557465	0.054994	1.576431	0.053981
1.0000	1.453108	0.154095	1.481562	0.039854
1.0330	1.407554	0.190953	1.522194	0.057226
1.0660	1.490666	0.207006	1.552079	0.046668

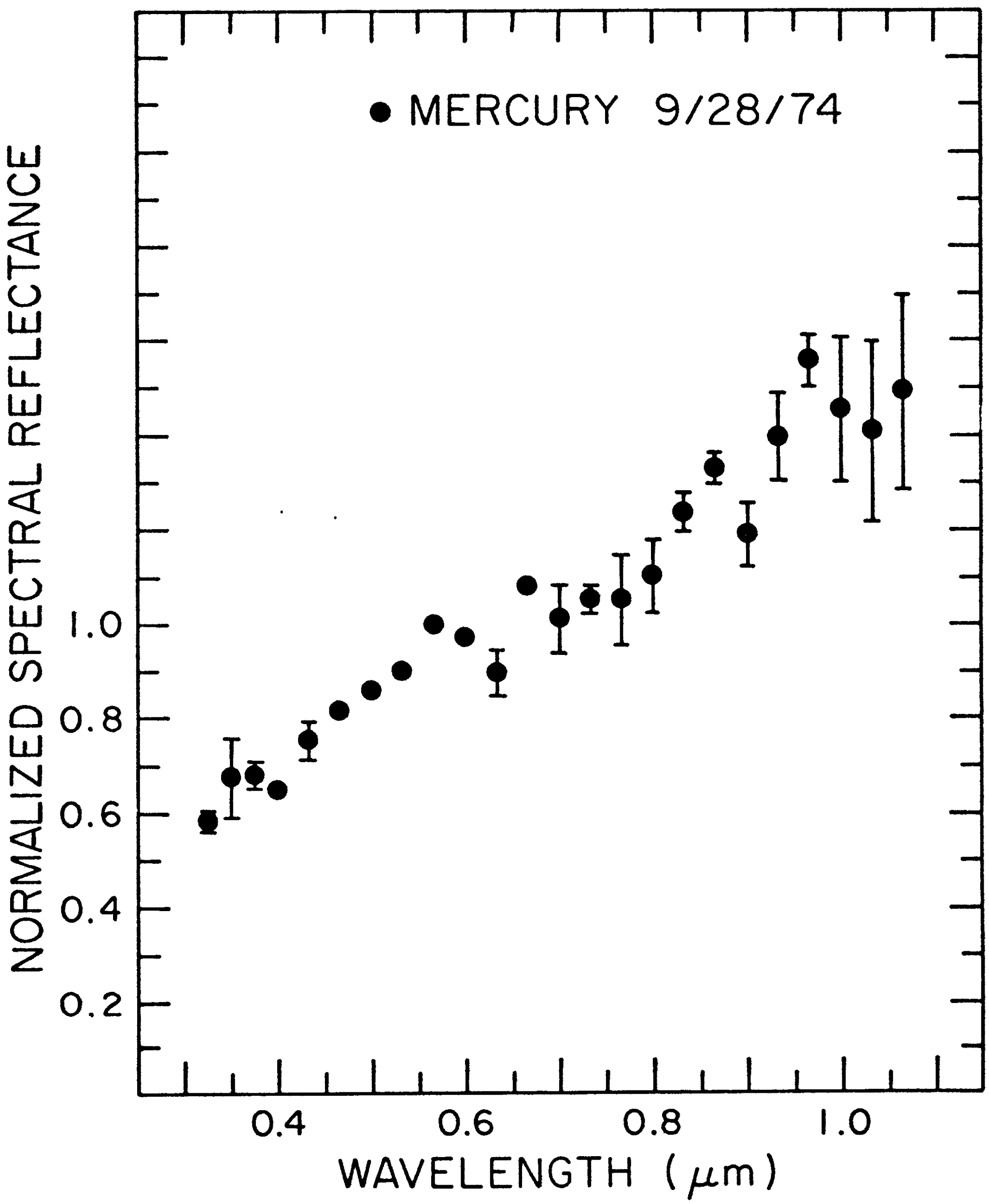


Figure III-B1. Mercury Reflectance September 28,1974
(A LYR)

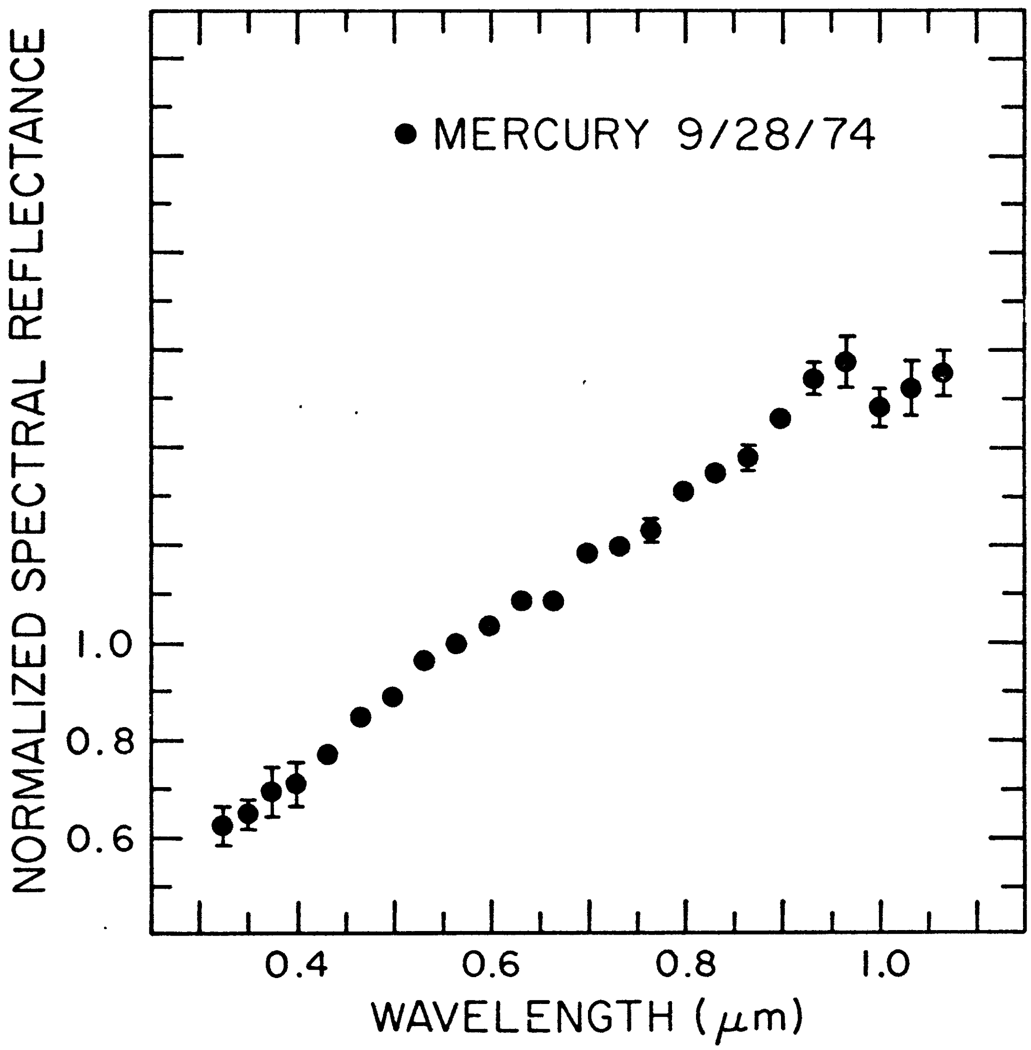


Figure III-B2. Mercury Reflectance September 28,1974
(109 VIR)

TABLE III - C. MERCURY REFLECTANCE

SEPTEMBER 29, 1974

Wavelength (μm)	(A LYR) Reflectance	Error	(109 VIR) Reflectance	Error
0.3250	0.601988	0.527942	0.758560	1.592503
0.3500	0.629405	0.238207	0.719872	0.679606
0.3750	0.660803	0.182051	0.736660	0.372300
0.4000	0.663826	0.114606	0.764791	0.268340
0.4330	0.736866	0.087341	0.808568	0.141815
0.4660	0.842099	0.041384	0.837632	0.092597
0.5000	0.890011	0.012745	0.899553	0.023021
0.5330	0.967975	0.019964	1.004039	0.011216
0.5660	1.000000	0.007268	1.000000	0.008638
0.6000	1.058342	0.008807	1.055729	0.007549
0.6330	1.093001	0.011548	1.111281	0.009994
0.6660	1.160732	0.011489	1.191239	0.017014
0.7000	1.142137	0.013989	1.253768	0.018059
0.7330	1.200397	0.005259	1.317478	0.021438
0.7660	1.309799	0.006344	1.360407	0.012826
0.8000	1.353867	0.012977	1.374475	0.014357
0.8330	1.414235	0.012552	1.470853	0.011351
0.8660	1.481579	0.021024	1.544397	0.013664
0.9000	1.479344	0.012010	1.616561	0.014067
0.9330	1.549214	0.011021	1.640870	0.025782
0.9960	1.662749	0.012609	1.643567	0.015824
1.0000	1.511640	0.004632	1.543180	0.014148
1.0330	1.700312	0.014445	1.643023	0.010003
1.0660	1.792216	0.012229	1.674399	0.012223

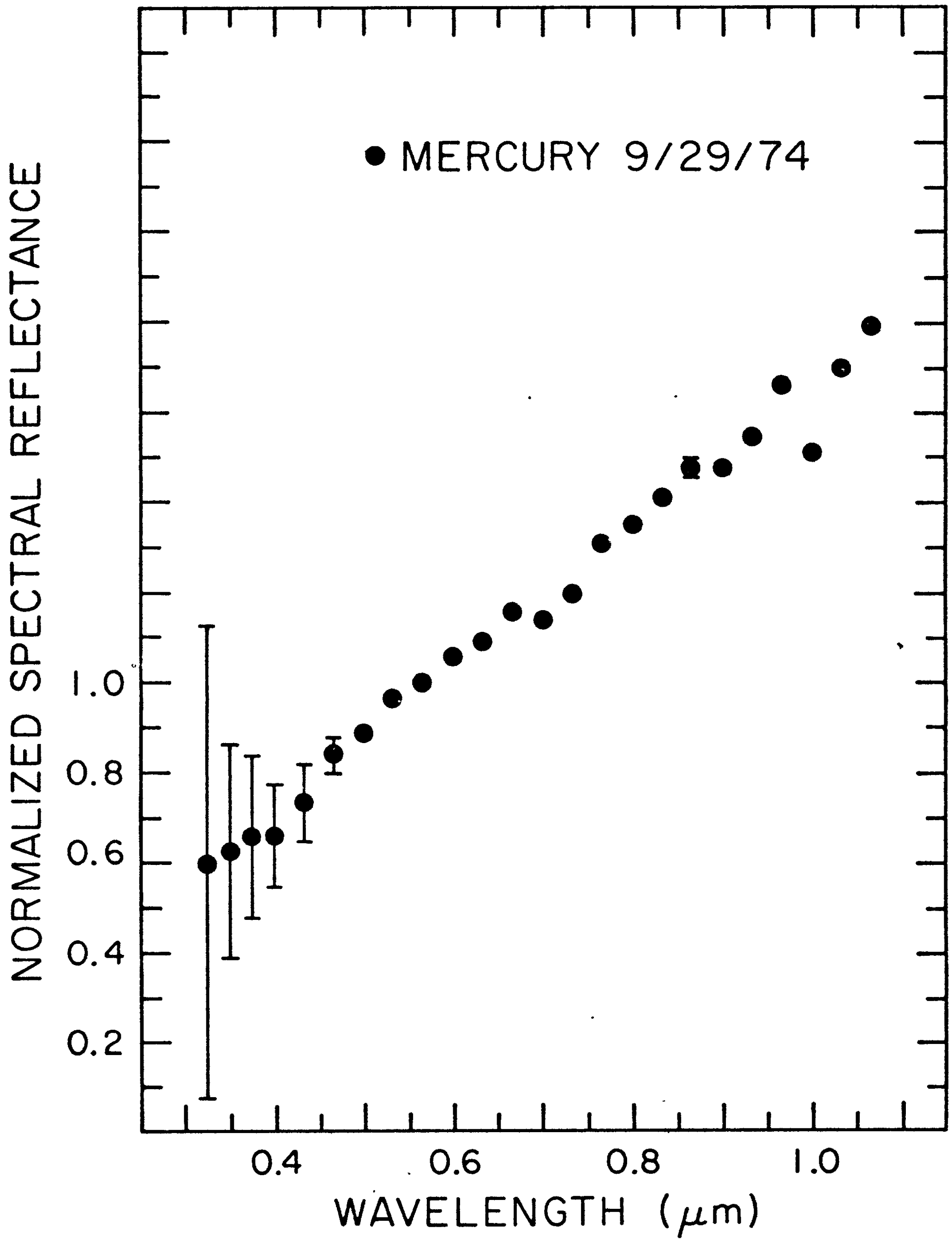


Figure III-Cl. Mercury Reflectance September 29,1974 (A LYR)

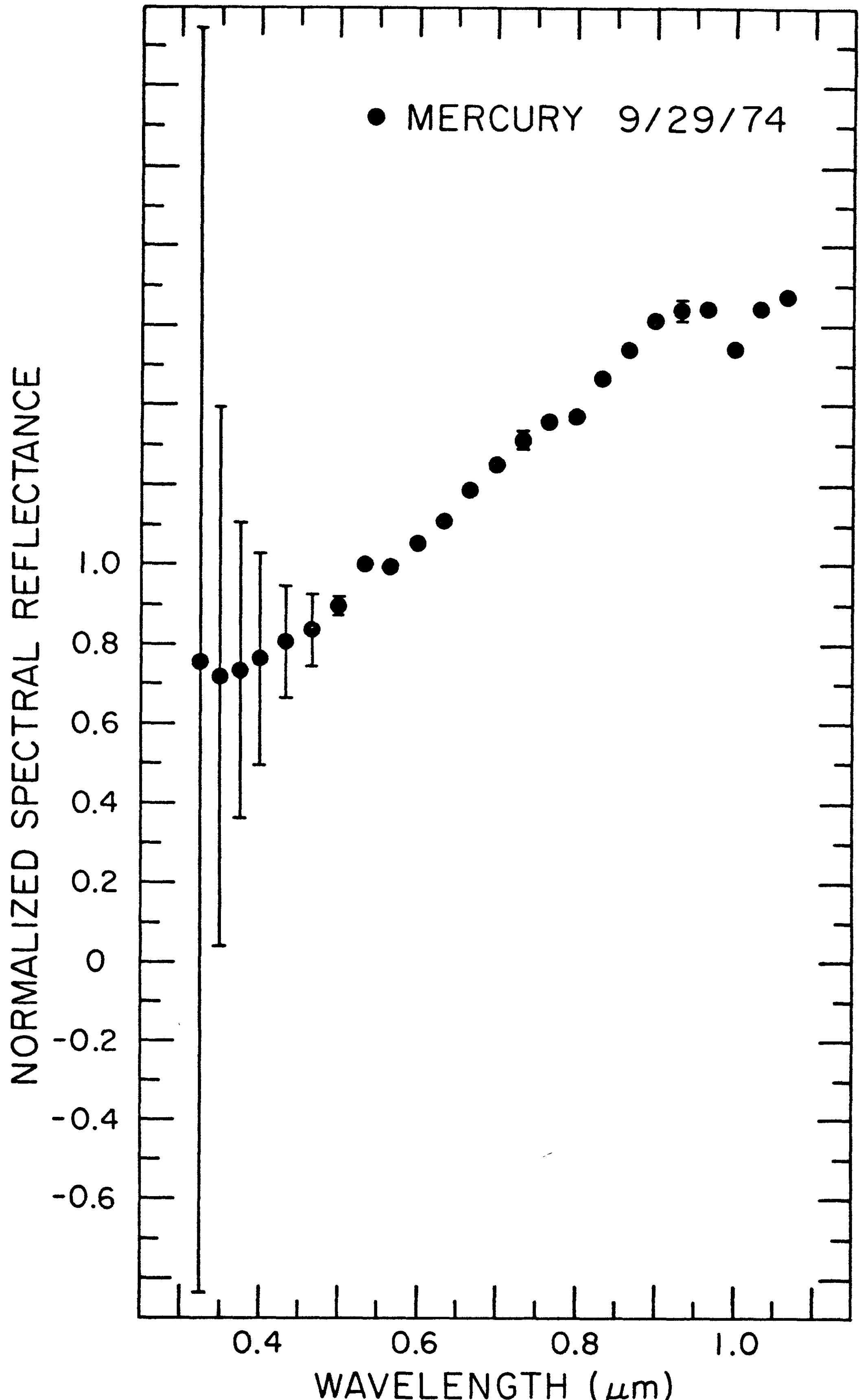


Figure III-C2. Mercury Reflectance September 29,1974 (109 VIR)

TABLE III - D. MERCURY REFLECTANCE

SEPTEMBER 30, 1974

(109 VIR)

Wavelength (μm)	Reflectance	Error
0.3306	0.439497	0.040358
0.3428	0.551660	0.063188
0.3812	1.045370	0.098823
0.4037	0.655268	0.049382
0.4370	0.787513	0.057022
0.4716	0.836672	0.015808
0.5033	0.927769	0.023740
0.5383	0.992615	0.012887
0.5659	1.000000	0.013547
0.6050	1.085423	0.004131
0.6376	1.215773	0.026748
0.6696	1.152411	0.027769
0.7010	1.193933	0.040726
0.7348	1.262146	0.029575
0.7685	1.282186	0.024608
0.8006	1.433907	0.036700
0.8348	1.465038	0.034195
0.8679	1.611084	0.046384
0.9020	1.559870	0.034780
0.9336	1.427897	0.028843
0.9667	1.576502	0.035178
0.9980	1.606198	0.029222
1.0340	1.862147	0.062803
1.0630	1.782618	0.111055

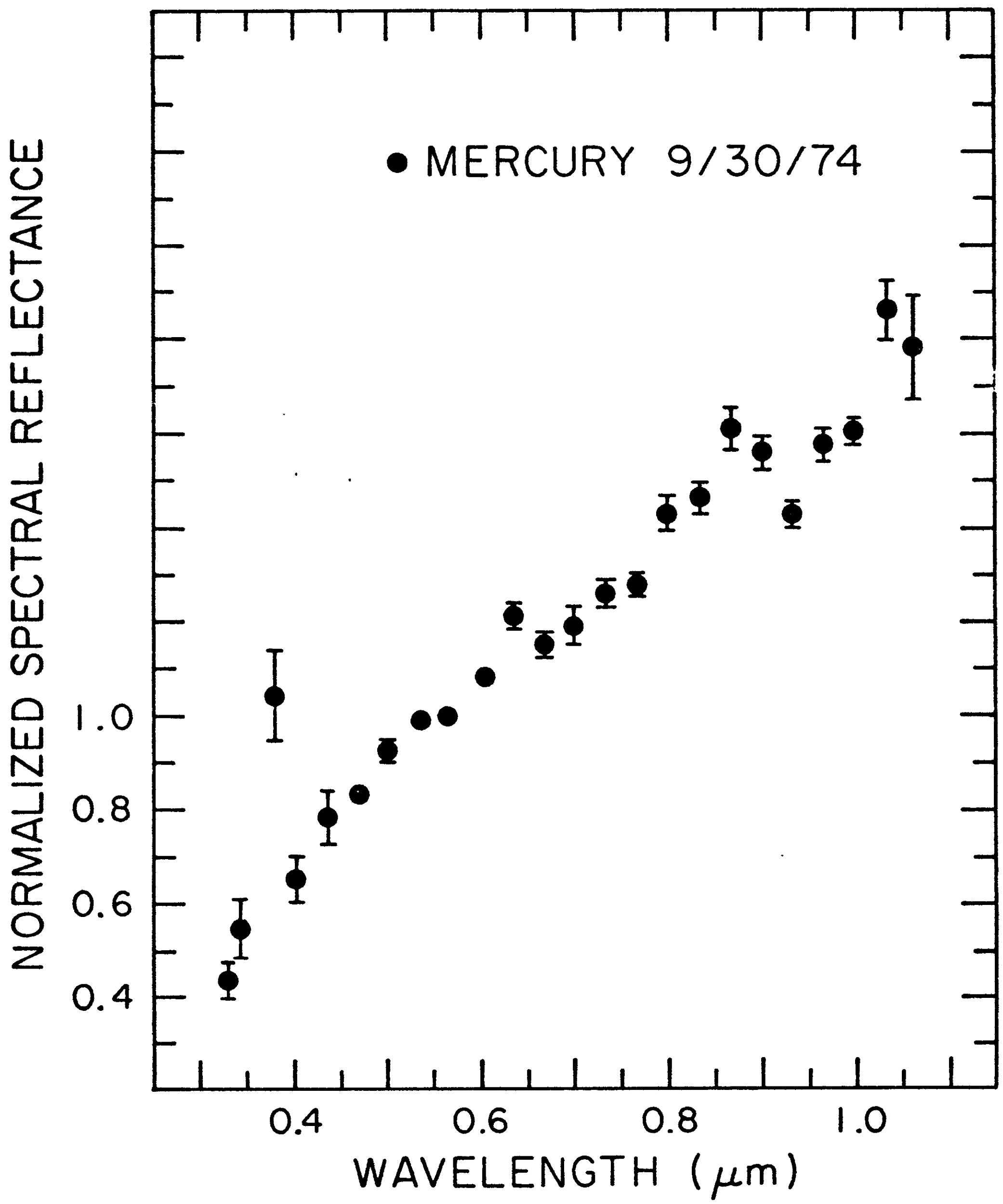


Figure III-D. Mercury Reflectance September 30,1974 (109 VIR)

TABLE III - E. MERCURY REFLECTANCE

OCTOBER 1, 1974

(109 VIR)

Wavelength (μm)	Reflectance	Error
0.3250	0.630365	0.047247
0.3500	0.635907	0.024498
0.3750	0.707248	0.058078
0.4000	0.707120	0.051064
0.4330	0.768029	0.028872
0.4660	0.842585	0.022840
0.5000	0.875429	0.010625
0.5330	0.958062	0.014566
0.5660	1.000000	0.018976
0.6000	1.071777	0.022545
0.6330	1.052002	0.017629
0.6660	1.003017	0.037180
0.7000	1.085870	0.052436
0.7330	1.111502	0.044871
0.7660	1.103178	0.064478
0.8000	1.084813	0.086627
0.8330	1.176674	0.070612
0.8660	1.141618	0.105043
0.9000	1.201864	0.079595
0.9330	1.497867	0.027045
0.9660	1.427330	0.047070
1.0000	1.219074	0.077632
1.0330	1.211314	0.114699
1.0660	1.336638	0.072712

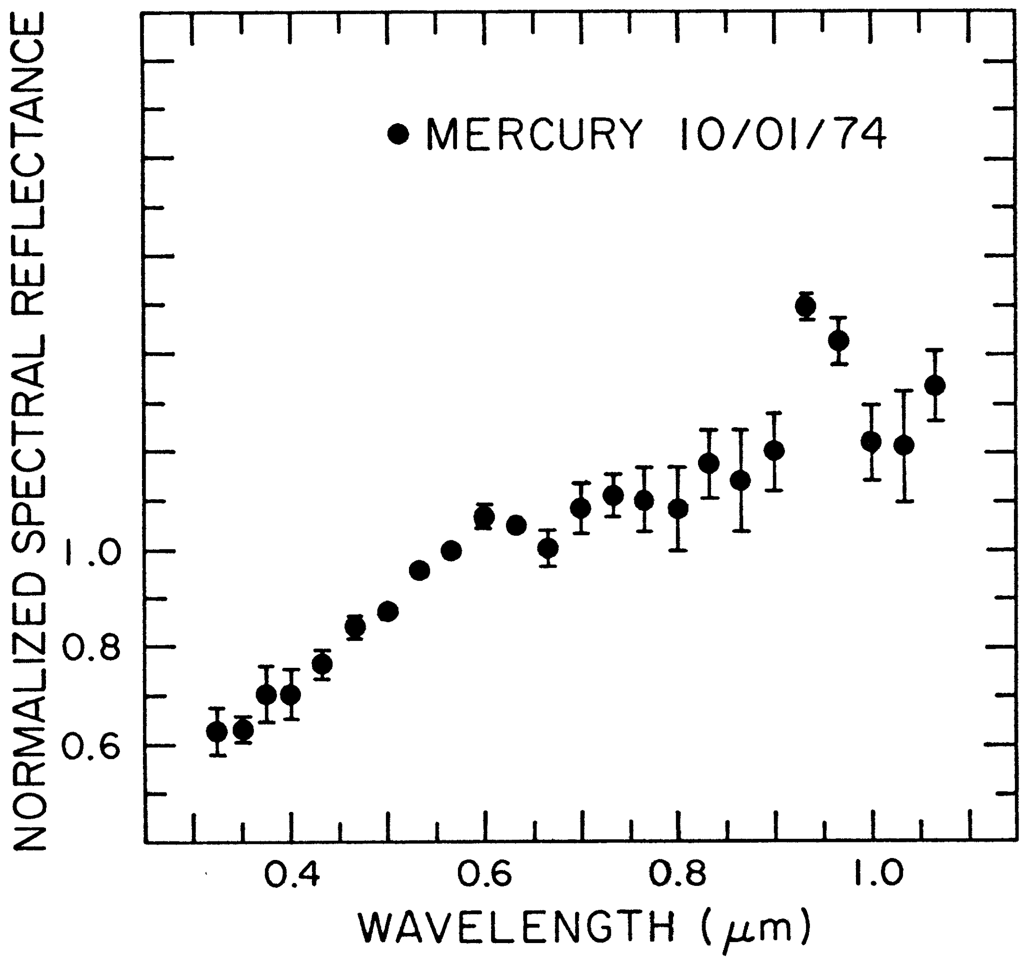


Figure III-E. Mercury Reflectance October 1,1974
(109 VIR)

TABLE III - F. MERCURY REFLECTANCE

OCTOBER 4, 1974

	(A LYR)		(109 VIR)	
Wavelength (μm)	Reflectance	Error	Reflectance	Error
0.3250	0.564153	0.036911	0.821945	0.155396
0.3500	0.647092	0.015831	0.728152	0.060197
0.3750	0.658720	0.012476	0.796638	0.078406
0.4000	0.685371	0.009008	0.806041	0.059008
0.4330	0.738558	0.006017	0.835477	0.030328
0.4660	0.808170	0.021214	0.871980	0.026739
0.5000	0.839375	0.004170	0.896870	0.007328
0.5330	0.921154	0.007399	0.994493	0.011316
0.5660	1.000000	0.008086	1.000000	0.009790
0.6000	1.010220	0.005038	1.063969	0.016346
0.6330	1.060733	0.003649	1.155697	0.009772
0.6660	1.102315	0.004589	1.210135	0.005704
0.7000	1.123647	0.019654	1.332454	0.022471
0.7330	1.160072	0.036864	1.279438	0.018894
0.7660	1.304564	0.042685	1.341001	0.022789
0.8000	1.327878	0.049336	1.423463	0.013495
0.8330	1.372854	0.070484	1.561116	0.027763
0.8660	1.310367	0.051392	1.554075	0.020163
0.9000	1.390160	0.062124	1.683071	0.046504
0.9330	1.483603	0.077701	1.864001	0.023849
0.9660	1.582499	0.014336	1.773103	0.014104
1.0000	1.444282	0.067861	1.771363	0.049727
1.0330	1.458876	0.106915	1.896690	0.055689
1.0660	1.528180	0.044312	1.905635	0.040602

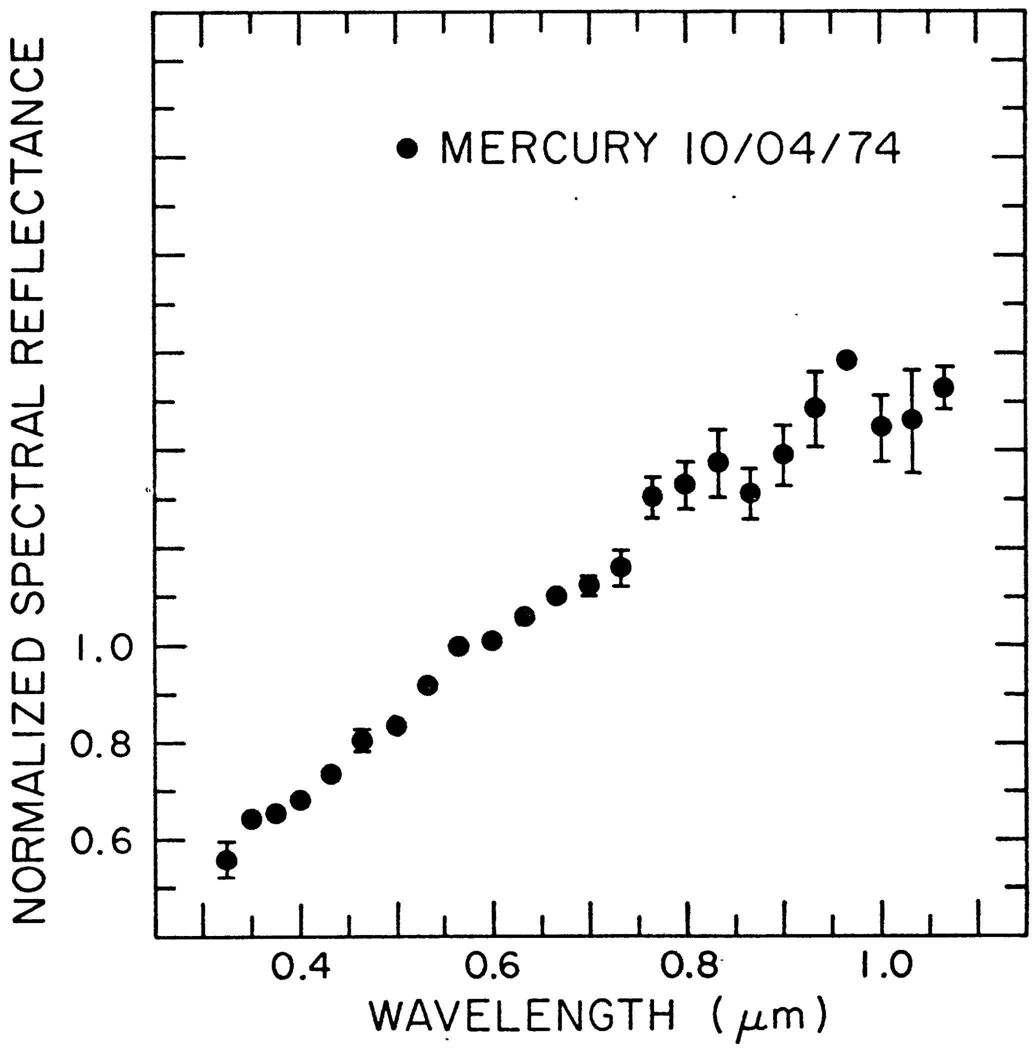


Figure III-F1. Mercury Reflectance October 4,1974
(A LYR)

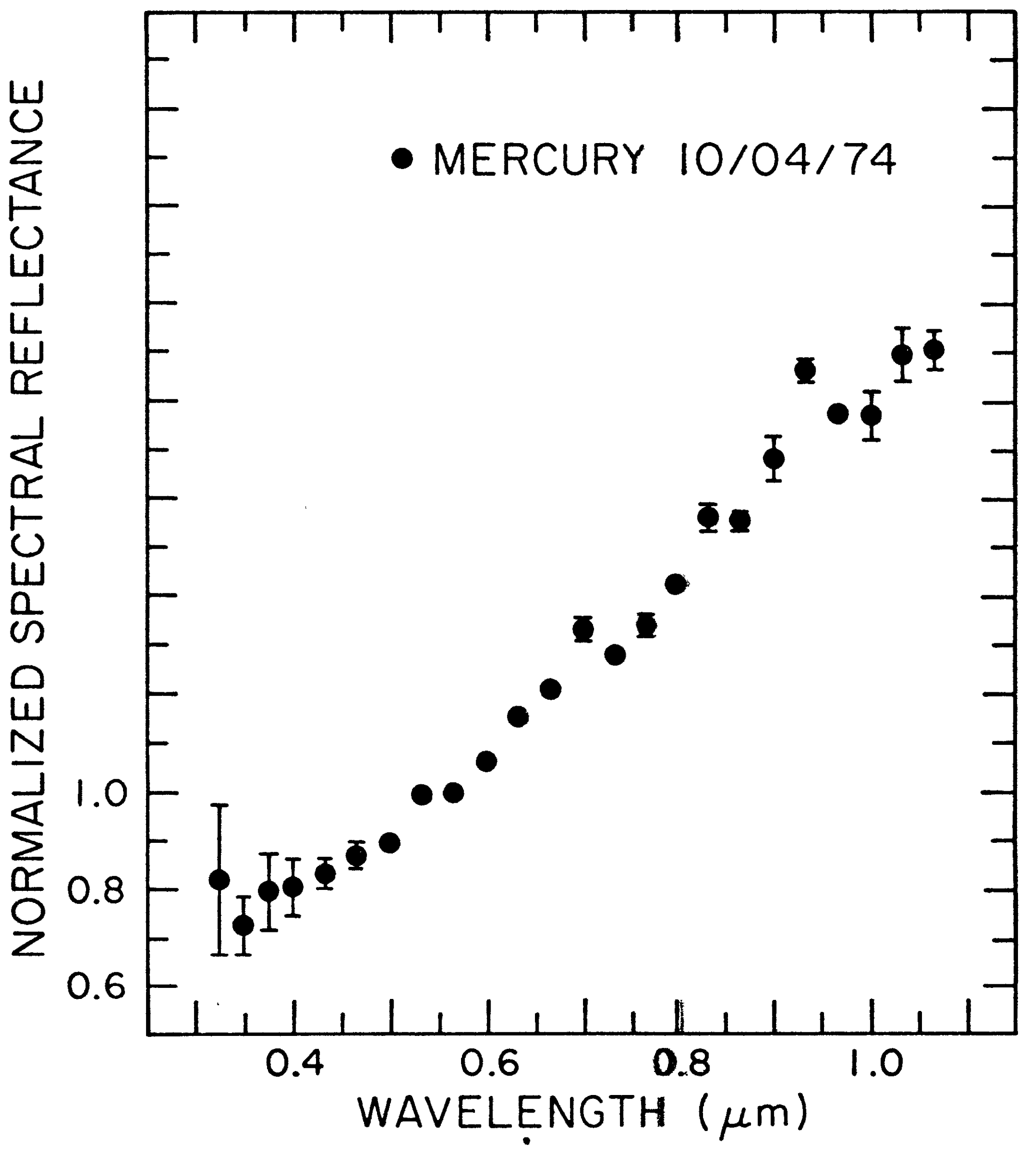


Figure III-F2. Mercury Reflectance October 4,1974
(109 VIR)

TABLE III - G. MERCURY REFLECTANCE

OCTOBER 5, 1974

(A LYR)

Wavelength (μm)	Reflectance	Error
0.3250	0.644639	0.515152
0.3500	0.643534	0.066506
0.3750	0.667372	0.315227
0.4000	0.680255	0.410132
0.4330	0.735385	0.197291
0.4660	0.803616	0.087496
0.5000	0.861634	0.021408
0.5330	0.949049	0.025253
0.5660	1.000000	0.022313
0.6000	1.041612	0.014374
0.6330	1.094894	0.009926
0.6660	1.128469	0.006589
0.7000	1.197731	0.009141
0.7330	1.254387	0.005378
0.7660	1.304607	0.011736
0.8000	1.261791	0.012910
0.8330	1.449665	0.013890
0.8660	1.501726	0.005701
0.9000	1.427579	0.013085
0.9330	1.583312	0.009609
0.9660	1.597190	0.012426
1.0000	1.610808	0.002689
1.0330	1.568101	0.006801
1.0660	1.681027	0.007140

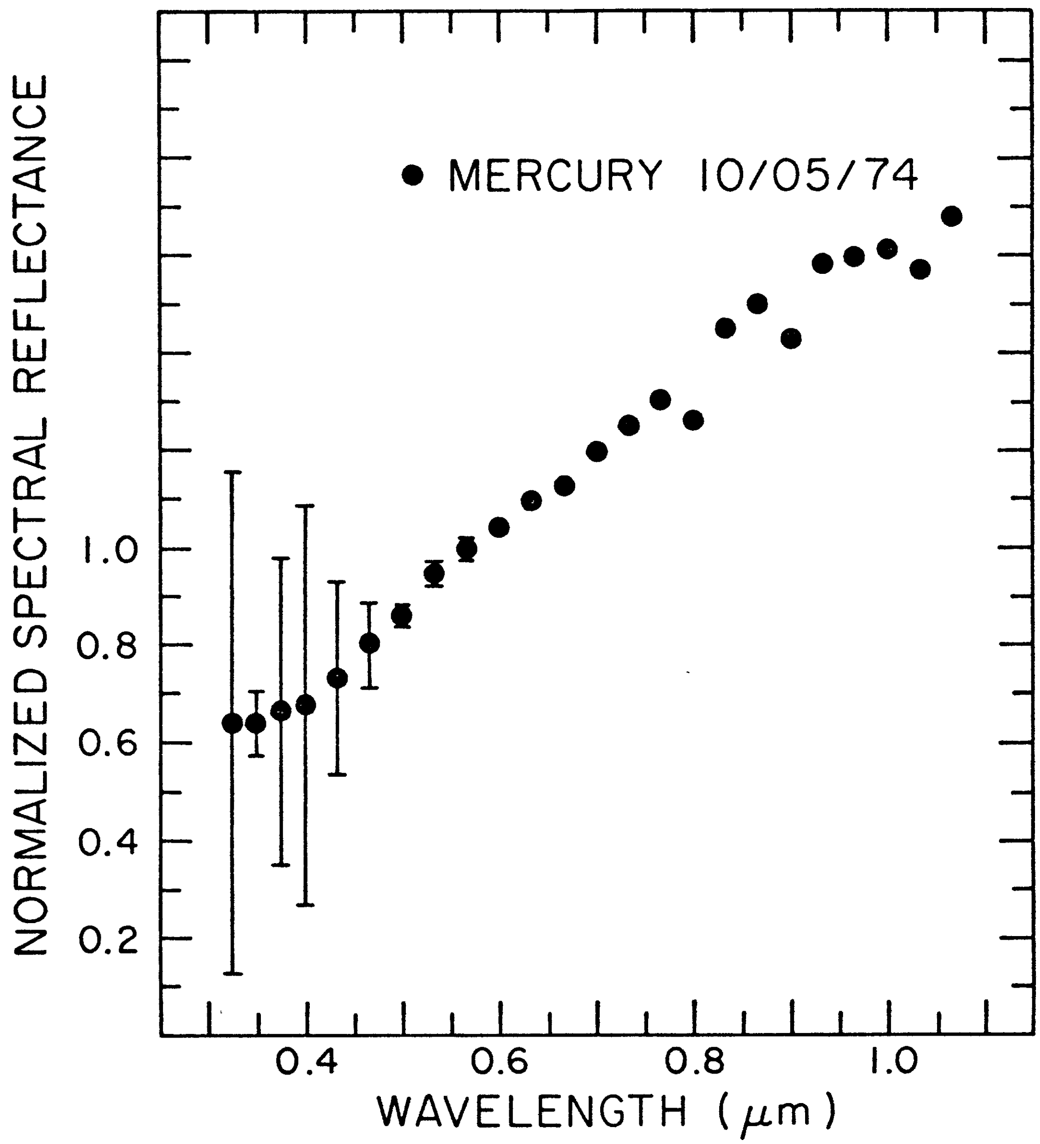


Figure III-G. Mercury Reflectance October 5,1974
(A LYR)

TABLE III - H. MERCURY REFLECTANCE

OCTOBER 6, 1974

(A LYR)

Wavelength (μm)	Reflectance	Error
0.3250	0.601562	0.010898
0.3500	0.648582	0.026837
0.3750	0.681580	0.020559
0.4000	0.675015	0.010686
0.4330	0.733731	0.011800
0.4660	0.833651	0.010649
0.5000	0.851492	0.007070
0.5330	0.927169	0.004771
0.5660	1.000000	0.010763
0.6000	1.029425	0.006908
0.6330	1.082751	0.015202
0.6660	1.165361	0.009571
0.7000	1.161598	0.017424
0.7330	1.269438	0.024092
0.7660	1.332189	0.026082
0.8000	1.386146	0.007687
0.8330	1.414154	0.009070
0.8660	1.458581	0.012118
0.9000	1.522350	0.028773
0.9330	1.502768	0.031049
0.9660	1.553091	0.024285
1.0000	1.590593	0.021872
1.330	1.577581	0.022846
1.0660	1.650924	0.026640

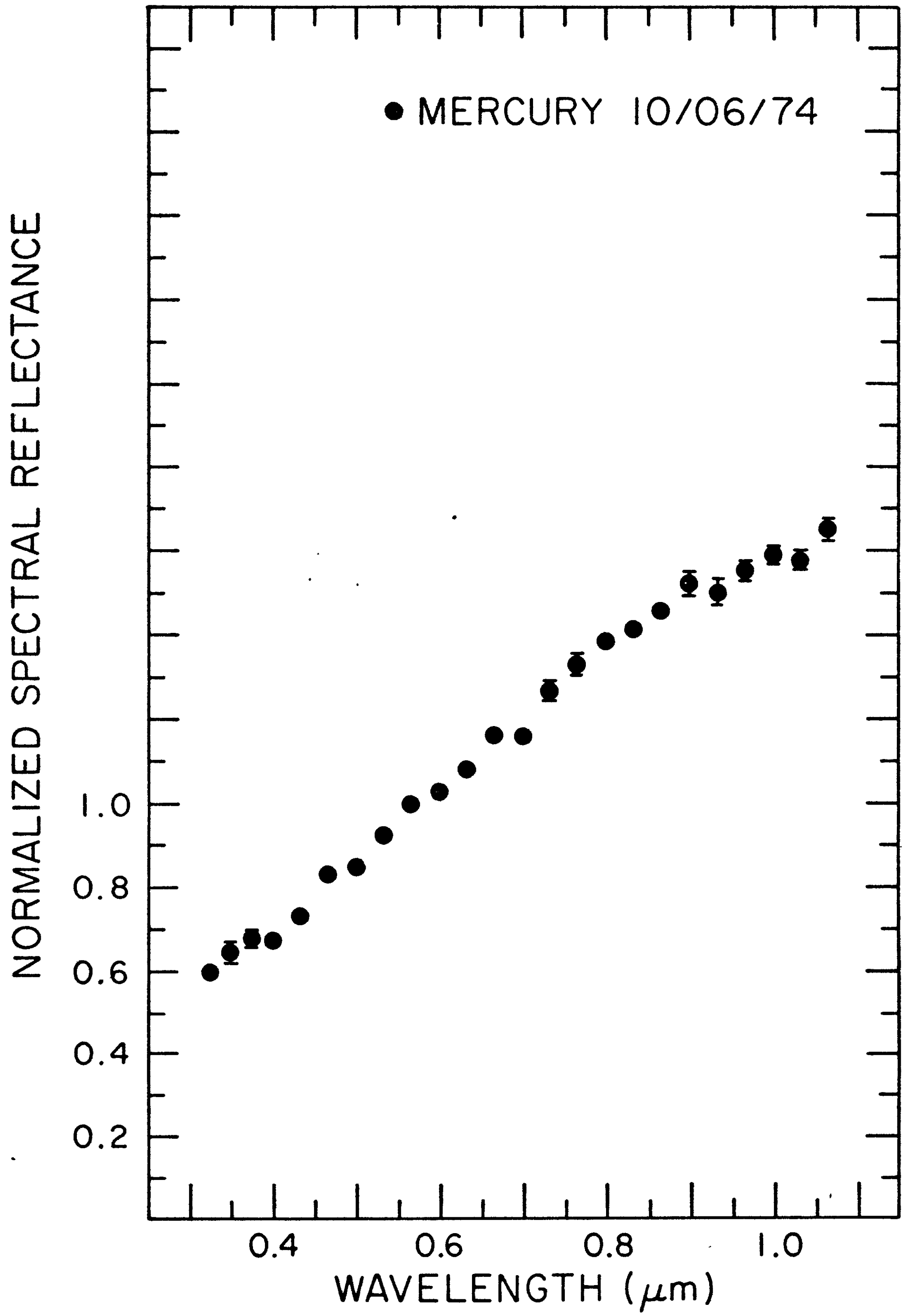


Figure III-H. Mercury Reflectance October 6,1974
(A LYR)

TABLE III - I. MERCURY REFLECTANCE

OCTOBER 7, 1974

(A LYR)

Wavelength (μm)	Reflectance	Error
0.3250	0.655730	0.027236
0.3500	0.663405	0.008678
0.3750	0.671785	0.006112
0.4000	0.696658	0.008286
0.4330	0.756172	0.003913
0.4660	0.811439	0.004077
0.5000	0.890308	0.008467
0.5330	0.950966	0.006907
0.5660	1.000000	0.009233
0.6000	1.039572	0.006207
0.6330	1.062332	0.009776
0.6660	1.104918	0.007238
0.7000	1.152978	0.017754
0.7330	1.183442	0.013930
0.7660	1.249236	0.018511
0.8000	1.278393	0.012511
0.8330	1.299241	0.015699
0.8660	1.302356	0.016403
0.9000	1.382748	0.023631
0.9330	1.429830	0.012727
0.9660	1.461695	0.013188
1.0000	1.442874	0.015976
1.0330	1.447499	0.024495
1.0660	1.501064	0.014026

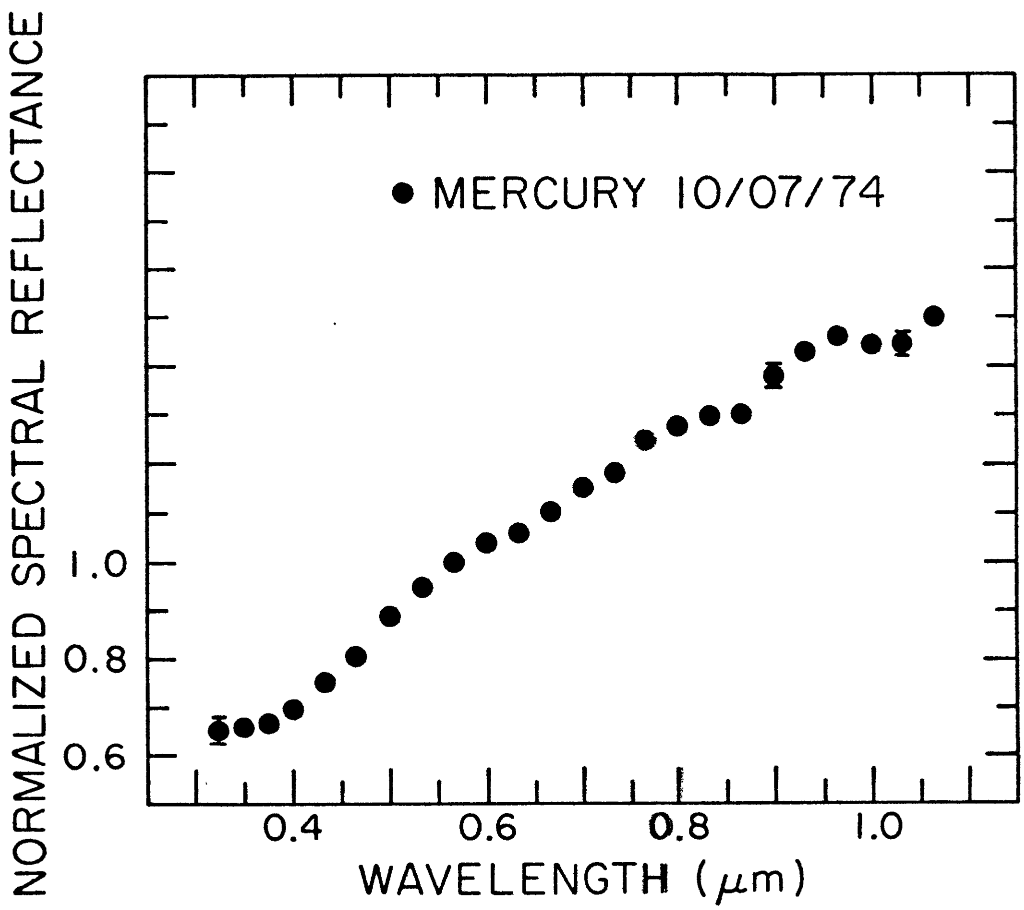


Figure III-I. Mercury Reflectance October 7,1974
(A LYR)

TABLE III - J. MERCURY REFLECTANCE

OCTOBER 8, 1974

Wavelength (μm)	Reflectance (A LYR)	Error
0.3250	0.575372	0.075998
0.3500	0.678586	0.017682
0.3750	0.712372	0.010175
0.4000	0.759157	0.016187
0.4330	0.721166	0.012337
0.4660	0.849415	0.007774
0.5000	0.829329	0.013988
0.5330	0.916453	0.010629
0.5660	1.000000	0.005934
0.6000	1.051765	0.007752
0.6330	1.161803	0.030831
0.6660	1.028826	0.019528
0.7000	1.094776	0.009435
0.7330	1.085954	01031813
0.7660	1.327869	0.024604
0.8000	1.245690	0.012199
0.8330	1.357456	0.012166
0.8660	1.394112	0.018919
0.9000	1.550138	0.057017
0.9330	1.567942	0.034603
0.9660	1.452845	0.009056
1.0000	1.556079	0.027784
1.0330	1.573602	0.018888
1.0660	1.840293	0.080922

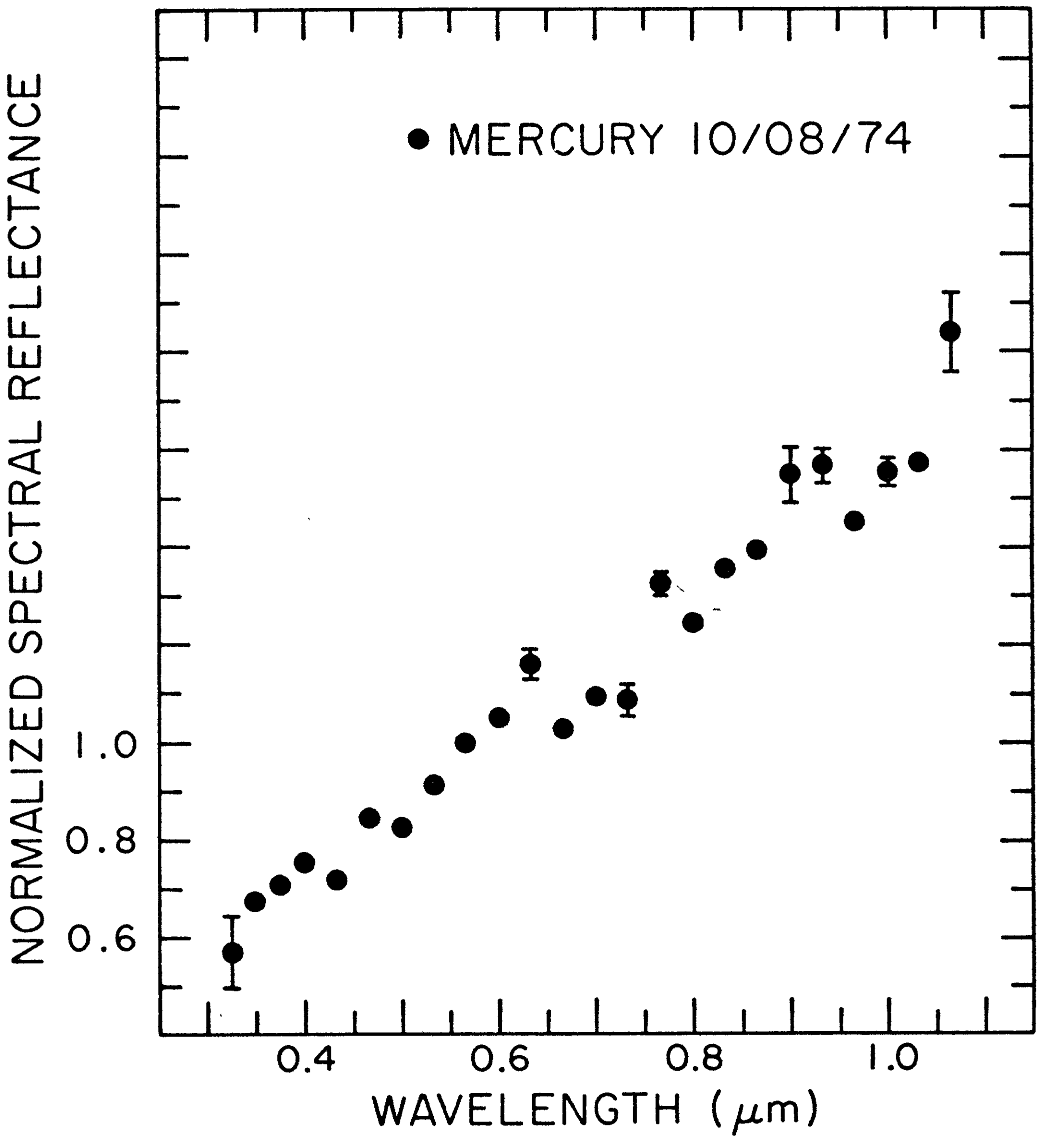


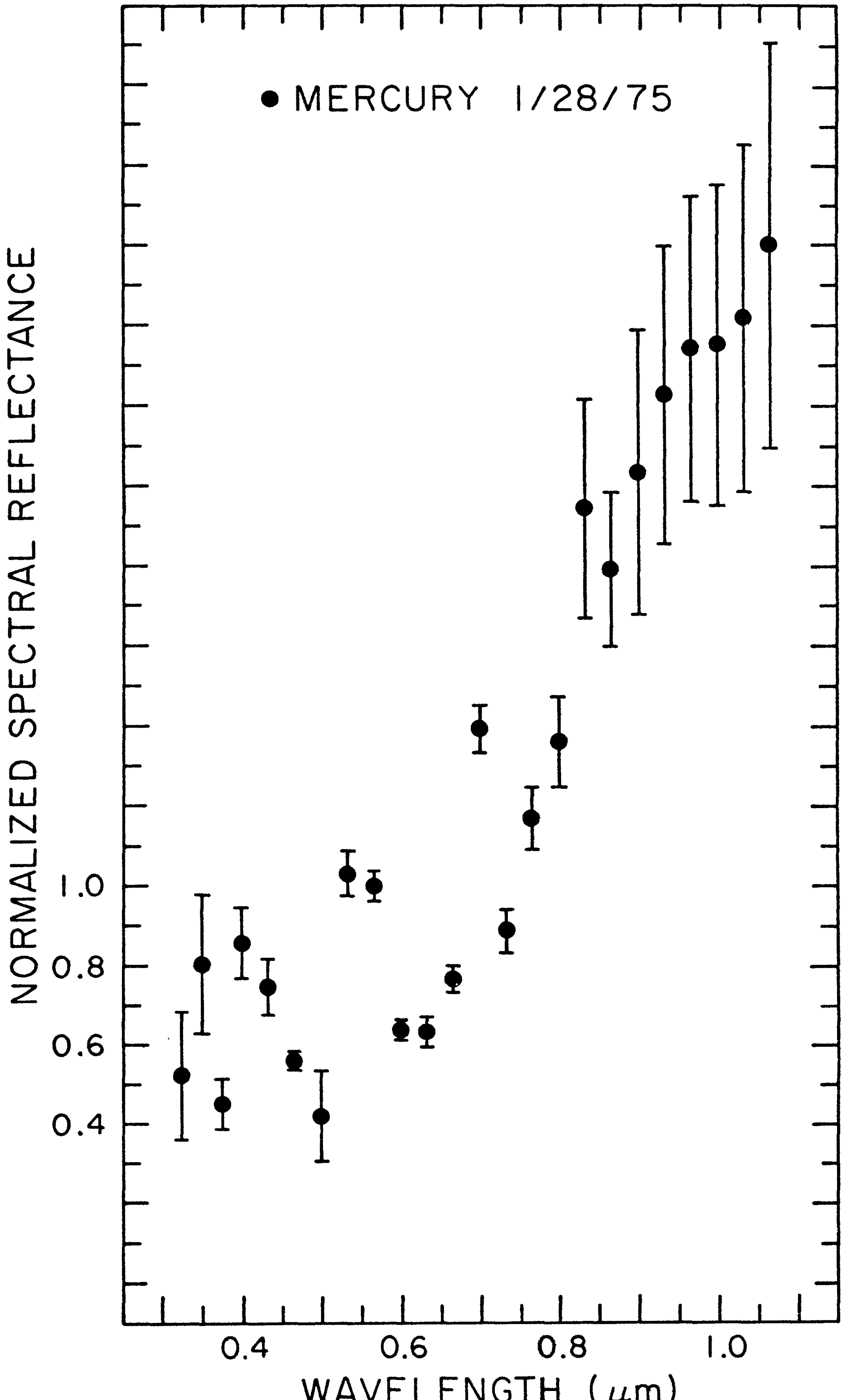
Figure III-J. Mercury Reflectance October 8,1974
(A LYR)

TABLE IV - A. MERCURY REFLECTANCE

JANUARY 28, 1975

(A PSA)

Wavelength (μm)	Reflectance	Error
0.3250	0.523651	0.162966
0.3500	0.805556	0.175554
0.3750	0:452411	0.064976
0.4000	0.858148	0.089405
0.4330	0.747308	0.072598
0.4660	0.561186	0.022826
0.5000	0.420992	0.115693
0.5330	1.031884	0.057841
0.5660	1.000000	0.039133
0.6000	0.638302	0.025244
0.6330	0.632614	0.037721
0.6660	0.768505	0.033711
0.7000	1.392802	0.060878
0.7330	0.887790	0.055563
0.7660	1.170365	0.079134
0.8000	1.361610	0.113702
0.8330	1.943526	0.273988
0.8660	1.791104	01193446
0.9000	2.032904	0.355730
0.9330	2.226521	0.372371
0.9660	2.340807	0.381503
1.0000	2.350564	0.401440
1.0330	2.417775	0.434282
1.0660	2.600601	0.508789



51 Figure IV-A. Mercury Reflectance January 28,1975
(A PSA)

TABLE IV - B. MERCURY REFLECTANCE

JANUARY 29, 1975

(A PSA)

Wavelength (μm)	Reflectance	Error
0.3250	0.818430	0.104974
0.3500	1.035945	0.120697
0.3750	0.590490	0.064379
0.4000	0.949646	0.092171
0.4330	0.903875	0.105808
0.4660	0.678667	0.044667
0.5000	0.488819	0.027578
0.5330	0.999411	0.061851
0.5660	1.000000	0.070187
0.6000	0.812777	0.029744
0.6330	0.827865	0.058053
0.6660	1.010027	0.094438
0.7000	1.856202	0.130777
0.7330	1.126025	0.095669
0.7660	1.434410	0.092400
0,8000	1.722025	0.102809
0.8330	2.193949	0.233118
0.8660	2.194180	0.105539
0.9000	2.254364	0.198267
0.9330	2.547517	0.174039
0.9660	2.574549	0.270109
1.0000	2.659112	0.340602
1.0330	2.925557	0.407346
1.0660	3.196962	0.336734

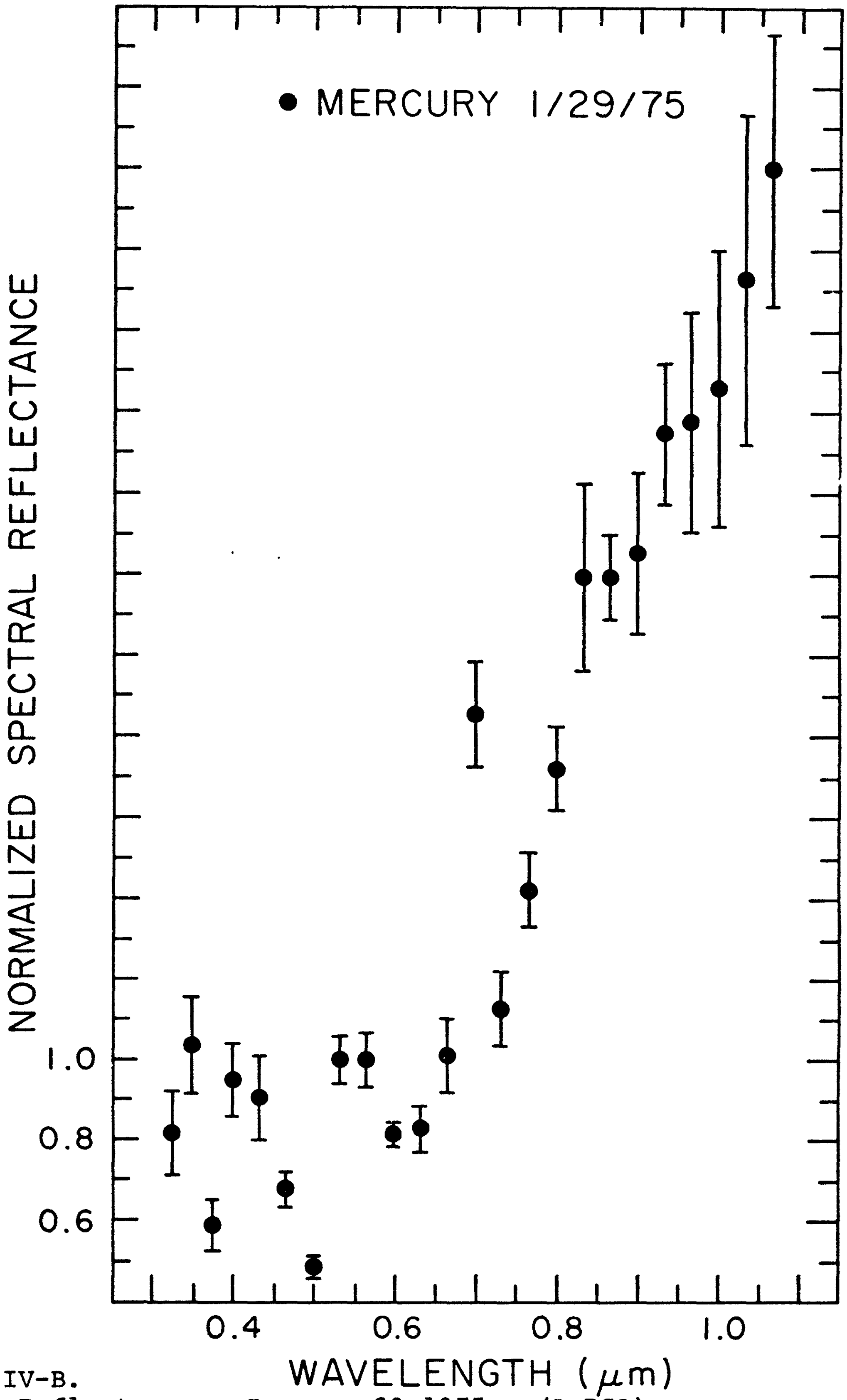


Figure IV-B.
Mercury Reflectance January 29,1975 (A PSA)

TABLE V - A. MERCURY REFLECTANCE

MARCH 7, 1975

Wavelength (μm)	Reflectance	(E AQR) Error
0.3250	0.507432	0.047727
0.3500	0.520323	0.018597
0.3750	0.632393	0.027693
0.4000	0.708983	0.040945
0.4330	0.822491	0.019529
0.4660	0.849132	0.019740
0.5000	0.968746	0.021968
0.5330	0.942329	0.008531
0.5660	1.000000	0.023184
0.6000	0.996271	0.021542
0.6330	0.964209	0.027729
0.6660	0.995041	0.024368
0.7000	0.983282	0.033338
0.7330	1.024837	0.032829
0.7660	1.067264	0.048927
0.8000	1.016928	0.048429
0.8330	1.115573	0.027631
0.8660	0.959658	0.030950
0.9000	1.060897	0.048659
0.9330	1.142997	0.070185
0.9660	1.211244	0.036804
1.0000	1.106050	0.077069
1.0330	1.083484	0.067540
1.0660	1.064982	0.058326

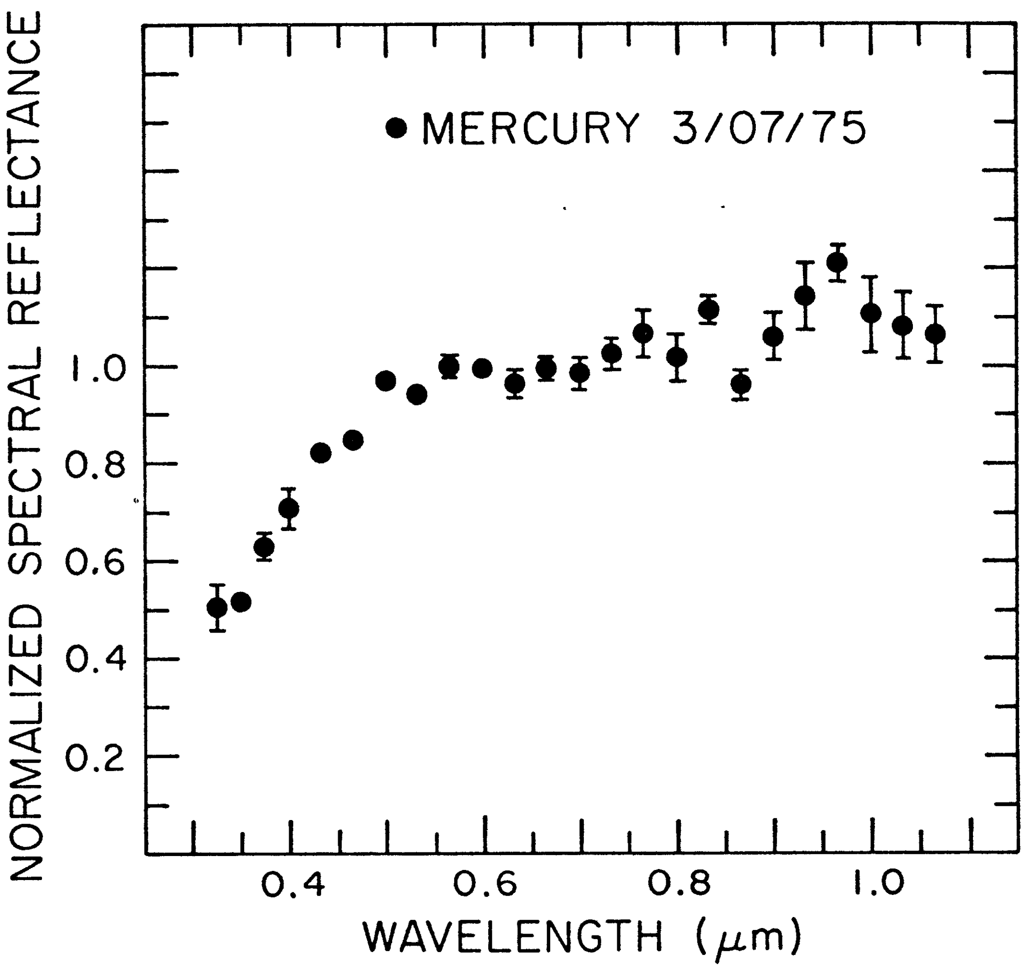


Figure V-A. Mercury Reflectance March 7,1975
(E AQR)

TABLE V - B. MERCURY REFLECTANCE

MARCH 8, 1975

Wavelength (μm)	Reflectance	(E AQR) Error
0.3250	0.507889	0.045930
0.3500	0.536510	0.015430
0.3750	0.555673	0.024553
0.4000	0.653567	0.021910
0.4330	0.762062	0.009668
0.4660	0.835904	0.013378
0.5000	0.912837	0.012737
0.5330	0.980007	0.008285
0.5660	1.000000	0.009478
0.6000	1.052864	0.006966
0.6330	1.091090	0.009079
0.6000	1.146145	0.006865
0.7000	1.161516	0.012073
0.7330	1.340631	0.019054
0.7660	1.351468	0.007690
0.8000	1.368803	0.013595
0.8330	1.403374	0.010721
0.8660	1.444045	0.021198
0.9000	1.436830	0.022589
0.9330	1.439198	0.016557
0.9660	1.434585	0.026455
1.0000	1.468576	0.028946
1.0330	1.492477	0.030527
1.0660	1.449150	0.042083

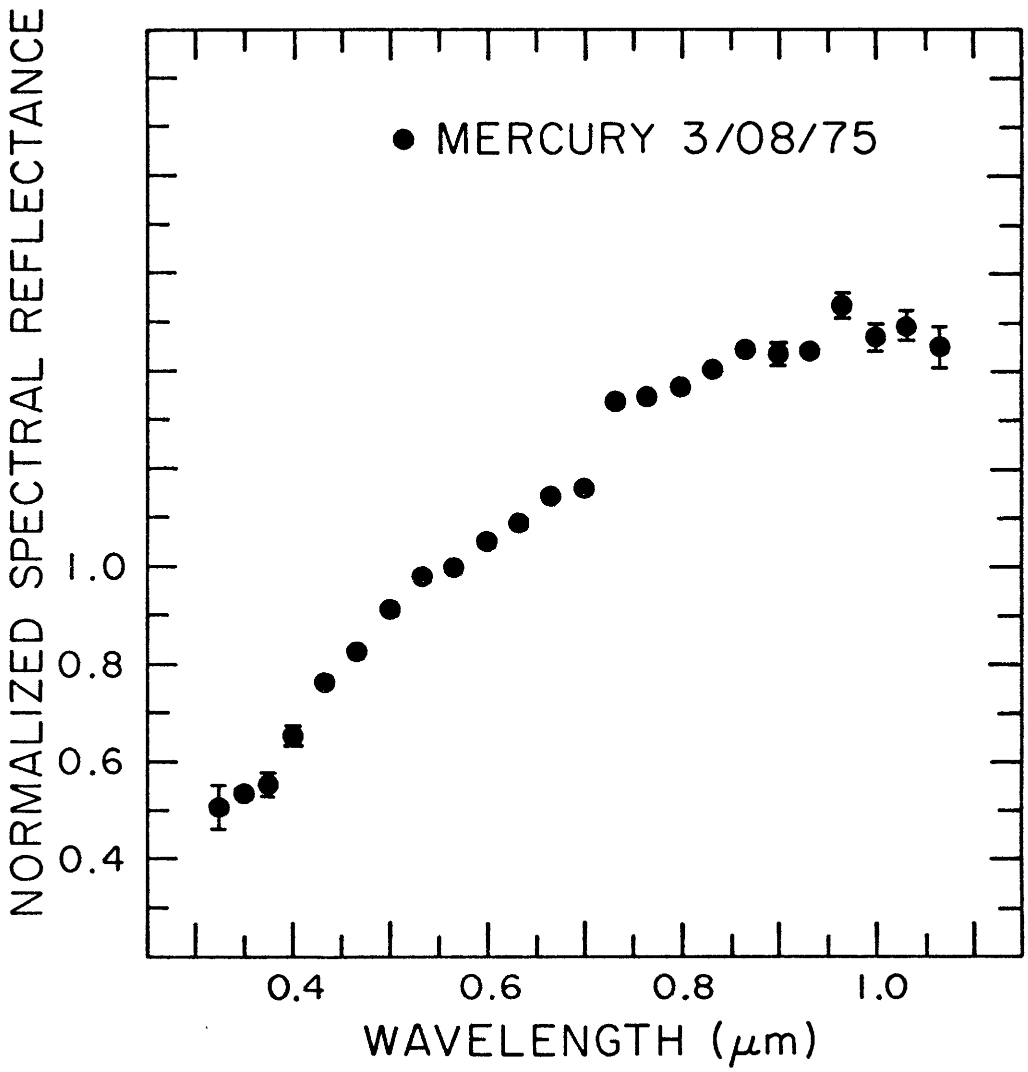


Figure V-B. Mercury Reflectance March 8,1975
(E AQR)

TABLE V - C. MERCURY REFLECTANCE

MARCH 9, 1975

Wavelength (μm)	Reflectance	(E AQR) Error
0.3250	0.491817	0.048380
0.3500	0.534720	0.022130
0.3750	0.524937	0.019368
0.4000	0.630552	0.015159
0.4330	0.738198	0.008585
0.4660	0.823283	0.013564
0.5000	0.931661	0.014448
0.5330	0.942894	0.006795
0.5660	1.000000	0.012124
0.6000	1.097445	0.008275
0.6330	1.148144	0.011811
0.6660	1.226546	0.015737
0.7000	1.202273	0.010300
0.7330	1.383618	0.011854
0.7660	1.411663	0.021642
0.8000	1.446766	0.016763
0.8330	1.422397	0.013077
0.8660	1.497319	0.014885
0.9000	1.538963	0.013630
0.9330	1.468035	0.020888
0.9660	1.587542	0.011057
1.0000	1.546774	0.018148
1.0330	1.476953	0.014885
1.0660	1.474808	0.039935

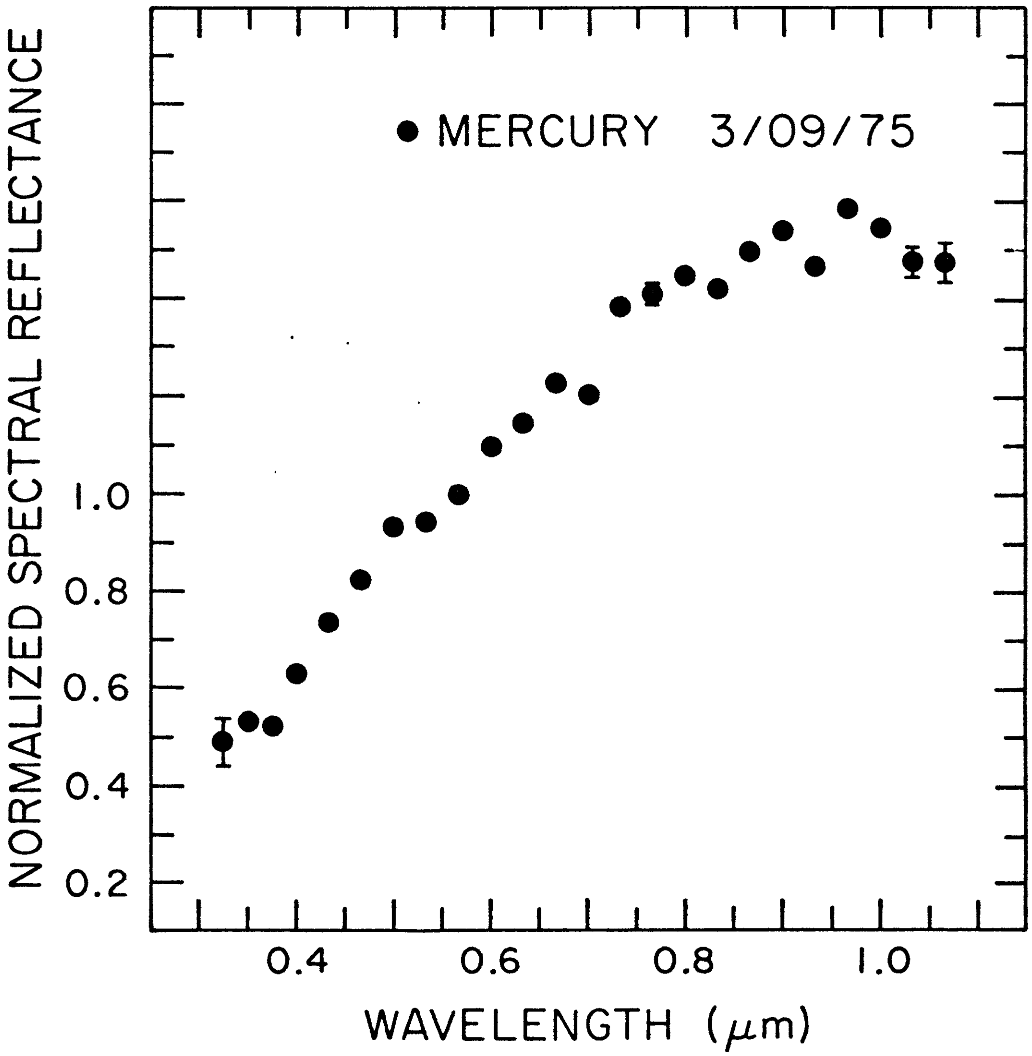


Figure V-C. Mercury Reflectance March 9,1975
(E AQR)

TABLE V - D. MERCURY REFLECTANCE

MARCH 10, 1975

Wavelength (μm)	Reflectance	(E AQR) Error
0.3250	0.444114	0.043881
0.3500	0.494514	0.017107
0.3750	0.496064	0.018712
0.4000	0.596090	0.015229
0.4330	0.697730	0.008430
0.4660	0.795581	0.011011
0.5000	0.912742	0.008205
0.5330	0.921297	0.011156
0.5660	1.000000	0.007237
0.6000	1.095661	0.006885
0.6330	1.131510	0.008772
0.6660	1.219557	0.011379
0.7000	1.177314	0.017413
0.7330	1.386118	0.012077
0.7660	1.380604	0.011281
0.8000	1.452819	0.010570
0.8330	1.413362	0.017539
0.8660	1.509338	0.016457
0.9000	1.488943	0.012824
0.9330	1.407278	0.015913
0.9660	1.505993	0.012767
1.0000	1.544287	0.018555
1.0330	1.516260	0.023985
1.0660	1.433639	0.018069

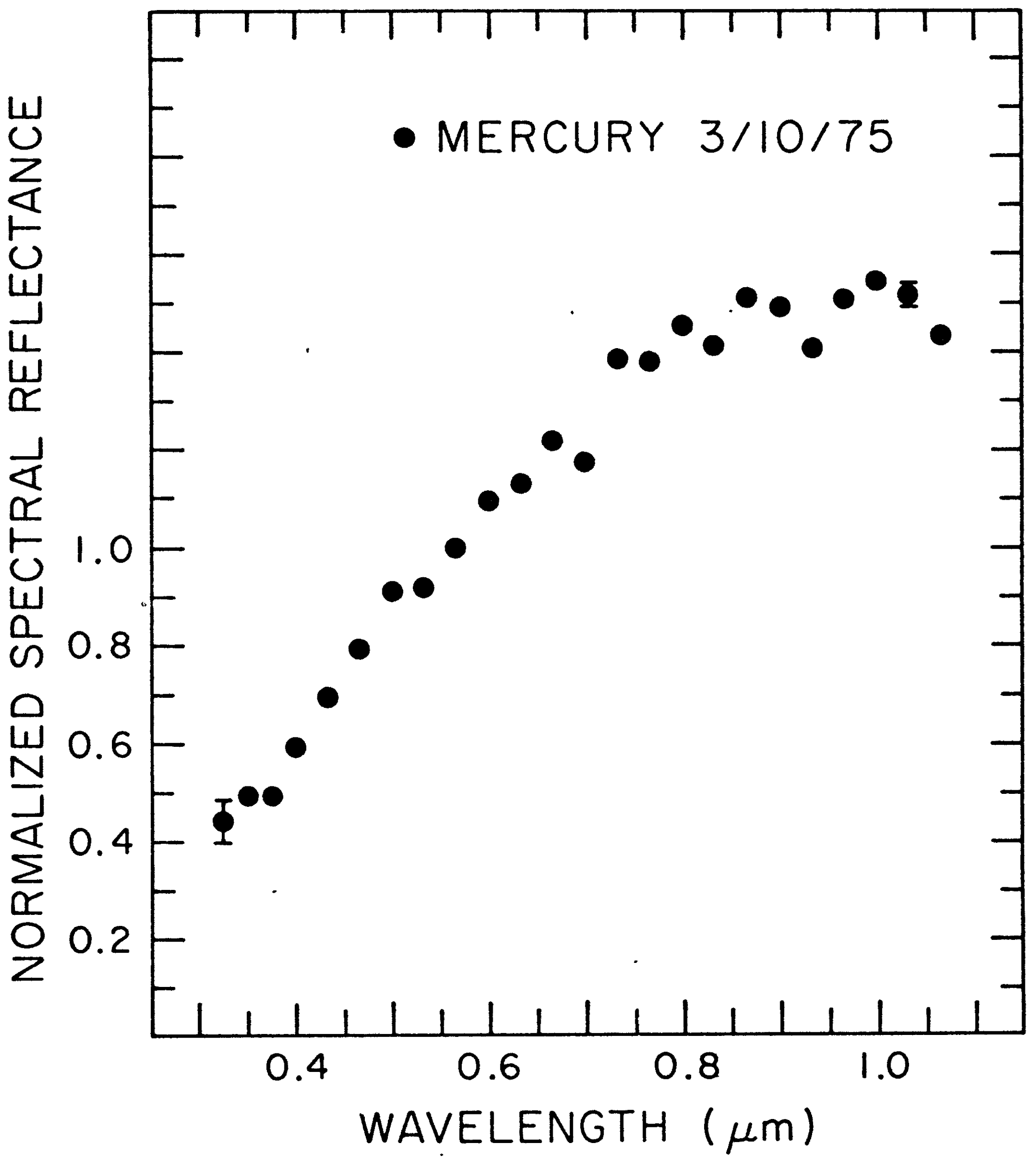


Figure V-D. Mercury Reflectance March 10.1975
(E AQR)

TABLE V - E. MERCURY REFLECTANCE

MARCH 11, 1975

Wavelength (μm)	Reflectance	(E AQR) Error
0.3250	0.471730	0.043062
0.3500	0.509043	0.016227
0.3750	0.590944	0.018866
0.4000	0.620081	0.014969
0.4330	0.725667	0.008626
0.4660	0.824195	0.010066
0.5000	0.914320	0.009763
0.5330	0.936510	0.008415
0.5660	1.000000	0.007998
0.6000	1.084226	0.008860
0.6330	1.138670	0.005928
0.6660	1.197480	0.006282
0.7000	1.197813	0.008411
0.7330	1.385094	0.012246
0.7660	1.391316	0.008989
0.8000	1.428145	0.011612
0.8330	1.406190	0.011419
0.8660	1.497556	0.018583
0.9000	1.492831	0.008365
0.9330	1.459593	0.020726
0.9660	1.577578	0.012547
1.0000	1.544216	0.015933
1.0330	1.497686	0.016509
1.0660	1.461397	0.023325

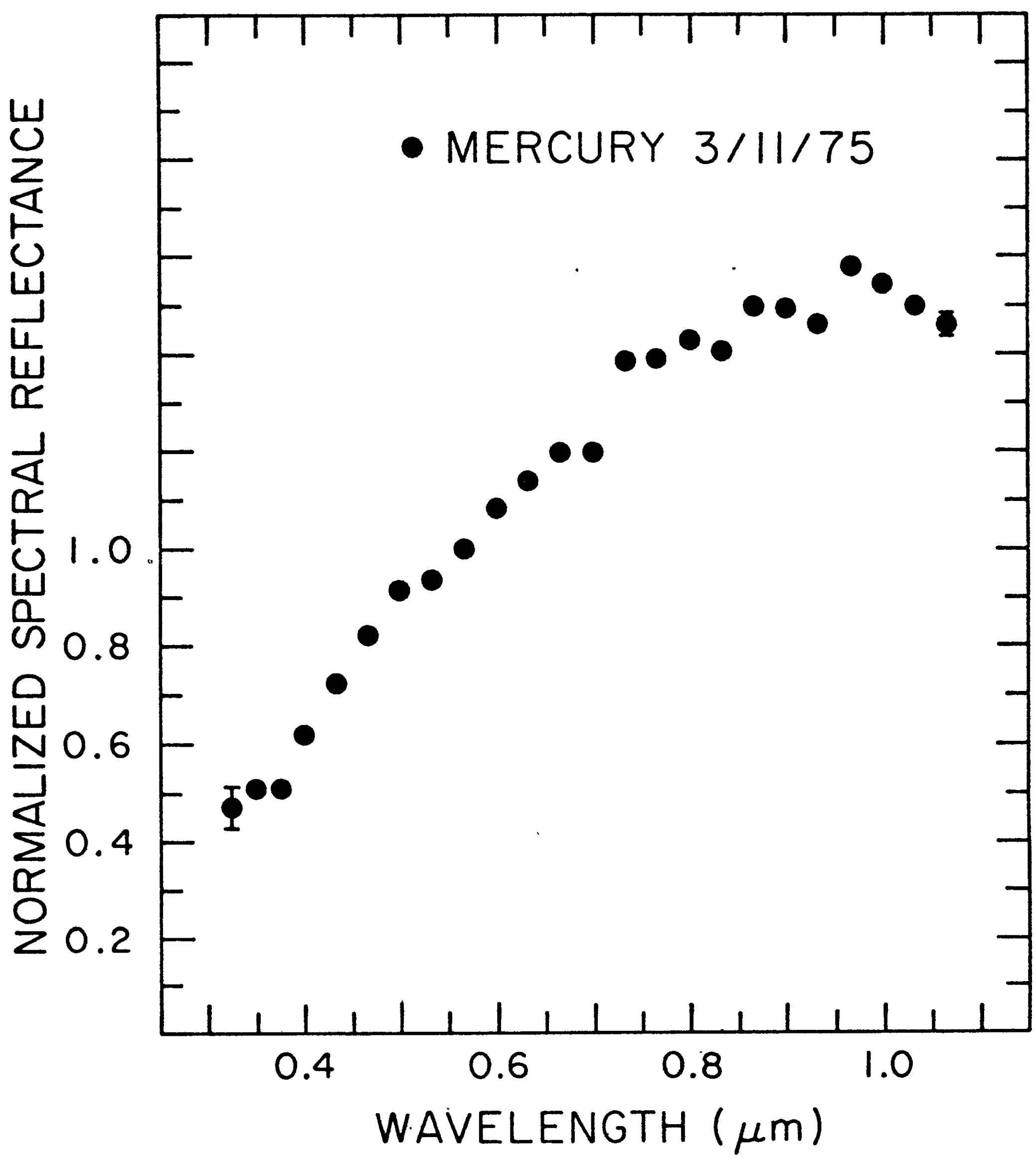


Figure V-E. Mercury Reflectance March 11,1975
(E AQR)

Two reflectance curves are given for a few days in the September/October run. Reasonable results were attained on these days for ratios of Mercury against two different standard stars observed in one day.

Only two of the three nights in the January run were reduced. January 28 and 29 reflectance values here were sporadic with large errors. The January 31 data were taken at higher airmasses under worse sky conditions than the other two nights. Also, G PSC, the standard star necessary for reducing the January 31 data, has not been calibrated yet. At this writing, a major error in the second data reduction program affecting the airmasses calibrated for the January data only has been discovered. Possibly, the January data can be reduced again with corrections for high photon counting effects in the data system and corrections in the data reduction programs.

Since E AQR/A LYR ratios had not been calibrated in the Spectrum 25B filters, E AQR/A LYR ratios for the Wallace filters were used for the March run. For most filters, the wavelength values of the two filter sets were close enough so that no corrections in star ratios were made. The exception was in the ultraviolet filters where values for Spectrum filters were interpolated from Wallace filter values. These values are listed in Table II-D.

Corrections were considered for the change in effective wavelength for the 24 filters due to increasing airmass (Elias,(2)), and due to amount of precipitable water in the atmosphere of Cerro Tololo during the observation: $\approx$ 2.4mm , $\approx$ 5.4mm, and $\approx$ 4.1mm for the September/October, January, and March runs respectively (Westphal and Neugebauer,(11)). Discussion concluded both that wavelength values for the filters were not known accurately enough, and changes in wavelength were so small, that any changes in the effective wavelength of the filters were negligible (Gaffey,(3)).

Another error in the data reduction programs affecting all of the data was also discovered at this writing. The latitude of Cerro Tololo stored in the program was -33°.15 instead of -30°.15 affecting the airmasses of the observations calculated for the data reduction. While this effect was small, corrections will be made to all of the data before publishing the Mercury reflectance values.

IV. Discussion and Conclusions

The spectral reflectance curves of Mercury for the September/October and March observing runs were compared and examined; interpretation of the January curves was considered useless until further corrections are made.

Generally, the curves all show the same increase in reflectance with increasing wavelength that was seen previously in McCord and Adams' data. Values for the ultraviolet filters correspond more closely to the December 25, 1969 data than to the low values of the March 12,1972 data. The new reflectance values are also less intense in the infrared filters. This increase in the radiation intensity in the ultraviolet, and decrease in the infrared, cause the September/October reflectance spectra to match spectra for the lunar maria and lunar uplands more closely. The March data have the same increasing reflectance but show a smooth turnover in the red and infrared. Although some September/October curves exhibit slight turnovers, those turnovers are not as strong as the ones present in the March curves. The turnovers may be due to the different standard stars used in the data reduction. E AQR was used for the March data; 109 VIR and A LYR were used for the September/October data. Closer examination showed that reflectance curves made with 109 VIR showed no turnover; curves made with A LYR show slight turnover. 109 VIR was used primarily at the beginning of the September/October run; A LYR primarily at the end. The question of whether these features are due to the use of different standard stars or due to differences seen in Mercury's surface mineralogy deserves further investigation.

Preliminary interpretations of the spectral reflectance curves (McCord,Adams,Gaffey,Huguenin,(8)) indicate that Mercury's surface composition is similar to that of the moon. The uniform strong blue and ultraviolet absorption and absence of ferrosilicate absorptions near 1 μm suggest the presence of dark glasses containing iron and titanium. This is in agreement with some solar condensation sequence models which predict iron in the terrestial planets. The curves suggest that Mercury has a somewhat reduced surface. Like the moon, Mercury is expected to contain little Fe^{3+}. The optical absorption of the glasses is probably primarily due to the intervalent charge-transfers of Fe^{2+}-Ti^{4+} and Fe^{o}-Fe^{2+}, implying the presence of Fe^{2+} on the surface. The Ti^{3+}-Ti^{4+} charge-transfer may also contribute somewhat to the absorption. Exact locations of the wavelengths of these charge-transfer absorption bands are still unknown. A thorough study of the final Mercury spectral reflectance curves is planned, including an examination of these values in energy space plus an examination of outside parameters which could affect the data.

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Appendix I. Grid Maps of Mercury

One objective of this work is to locate on the planet's surface for each day of observations the portion of Mercury's disk which was illuminated. To do this, values for the sub-earth point latitudes and longitudes on Mercury at 0hr U.T. were determined from information obtained from Pettengill (9). These values, plus additional information from the American Ephemeris and Nautical Almanac, were input into a program created to generate latitudes and longitudes of sub-solar points on Mercury for those days (Camichel and Dollfus, (1); Mink, (10)). The sub-earth and sub-solar point values, along with the average times of observation in U.T., can then be used in a planetary disk mapping program to produce a grid map of the planet. The terminator of the illuminated portion of the disk will also be drawn on the disk. The program for finding the sub-solar point values is still being debugged at this time. The sub-earth points and average times of observations are listed in Table VI. Time values for December 25, 1969, and March 12,1972 were estimated as the original logs were unavailable.

Table VI. Sub-Earth Point Coordinates and Average Times of Observations for Mercury

Date	0hr U.T. Sub-Earth Point Latitude	Longitude	Average Times of Observations (U.T.)
27 Sep 74	4°.6362	187°.0524	18^h 24^m
28 Sep 74	4.6208	192.0616	18 15
29 Sep 74	4.6054	197.0708	18 25
30 Sep 74	4.5900	202.0800	18 35
1 Oct 74	4.5708	207.2936	18 29
4 Oct 74	4.5132	222.9344	18 36
5 Oct 74	4.4940	228.1480	18 42
6 Oct 74	4.4680	233.6700	18 32
7 Oct 74	4.4420	239.1920	18 40
8 Oct 74	4.4160	244.7140	18 40
28 Jan 75	-10.0620	215.4330	16 57
29 Jan 75	-9.9252	222.1948	17 32
7 Mar 75	-4.9714	65.0232	7 12
8 Mar 75	-4.8842	69.6386	5 39
9 Mar 75	-4.7970	74.2540	5 32
10 Mar 75	-4.7154	78.7736	5 33
11 Mar 75	-4.6338	83.2932	5 33
26 Dec 69	-4.8294	246.3676	9 15
12 Mar 72	-5.9584	83.9382	11 23