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Dowling College
Oakdale, New York

Final Report

"Cometary Investigation During the Total Solar Eclipse of March 7, 1970"

National Aeronautics and Space Administration
Physics and Astronomy Programs
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Principal Investigator:

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Prof. Henry C. Courten

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Summary

The results of our 1970 solar eclipse observations are most promising. For the first time photographic data are available from two remote sites, while a third, independent site produced what is, apparently, a confirmatory observation of one of our targets.

Within what we consider the limits of our present photographic technique, in an apparently turbulent atmosphere, our observation sites in southwestern Mexico and North Carolina recorded seven common plate images which cannot be identified as either stellar or asteroidal. A third observer, near Hampton, Virginia, photographed the brightest of the seven interesting images.

The data obtained, as well as speculation with regard to the nature of the phenomenon, was presented at the 1970 Solar Eclipse Symposium of the Fourteenth COSPAR Meeting, Seattle, Washington in June 1971.

Observation Site

The path of totality for the March 1970 solar eclipse extended from the southwestern Mexican coast all the way to Nova Scotia. Based on meteorological forecasts, two observation sites were selected approximately 1600 km apart. Originally, Site One was to have been at Puerto Angel on the Mexican coast. A preliminary site survey expedition (see NSF Eclipse Bulletin E) indicated that this location was accessible; however, the vehicles available to our party in Mexico City were unsuitable for navigating the very rough mountain road between the town of Miahuatlan and the coastal port. Consequently, Site One was located just outside Miahuatlan.

Site Two was located just outside Elizabethtown, North Carolina.

Equipment

Site One was equipped with the following:

- 2 ea. MOTS-40 cameras of 1000 mm focal length, operating at f5. One camera was equationally-mounted and sidereally driven, the other was hard mounted. Both cameras were loaned to Dowling College for the eclipse expedition by NASA's Goddard Space Flight Center.
- narrow-band scanning photometer of 250 mm focal length, operating at f1.2 with selective filters peaking at .3883μ and .5890-96μ. A complete description of the photometer, in the form of an unpublished paper, appears as Appendix I.

Site Two was equipped with a modified Kodak K40 camera of 1200 mm focal length, operating at f7.1.

All photographs were made on Kodak 038-01 glass plates (approx. 200 x 250 mm).

Results

Five, good quality plates, were obtained from each site. A number of coincident "pairs" of non-stellar images were found between observation sites. The probability that these images represent real objects in space is rather high. Significantly, a third observation site, at Hampton, Virginia, photographed the brightest of the 'objects' recorded by our two stations.

The complete results of our comet searches are summarized in Appendix II, the abstract of a paper presented by the principal investigator at the 1970 Solar Eclipse Symposium of the Fourteenth COSPAR Meeting, held in Seattle, Washington during June 1971.

Dr. Cornelius deJager, senior editor of Solar Physics, has advised that an abstract will be published in a forthcoming issue of the journal.

Future Plans

Tentative plans have been formulated to monitor both the 1972 and 1973 total solar eclipses from at least two ground stations. The results from the well-covered 1970 event have strongly pointed out the necessity for seeking corroborating data from multiple sites.

Personnel

Site One - Mexico

Prof. Donald B. Albert - Adelphi University

Mr. Donald W. Brown - Dowling College

Prof. Henry C. Courten - Dowling College

Mr. Mihran Miranian - U.S. Naval Observatory

Site Two - North Carolina

Mr. Lawrence Cafiero - Grumman Aerospace Corporation

Mr. Harold Dunayer - Grumman Aerospace Corporation

Site Three - Virginia

Mr. Sheldon Smith - NASA Ames Research Laboratory

APPENDIX I

A Scanning Narrow-band Photometer for Comet Detection

Henry C. Courten

Introduction

Four times during the past century comets have been visually observed in the near-vicinity of the sun during total eclipse. In 1963 a serious attempt at broadfield photography by Donn and Dossin (ref. 1) uncovered a singular object which appeared to be cometary in nature. More sophisticated efforts by Courten, et al, in 1966 (ref. 2) and 1968 (ref. 3) resulted in finding ten and nine non-stellar objects, respectively, within ten solar radii.

Two serious drawbacks accompanied these early comet hunting experiments: 1) only single station observations were made in each instance and 2) the non-stellar, and possibly cometary objects, lie near the very limits of the photographic plates (Kodak type 038-01) and are difficult to differentiate from plate defects. The images recorded in 1966 had an equivalent visual magnitude of +7 to +9, those of 1968 occurred between +7 and +11. The stellar limit of the plates is approximately +12 for spectrally cool stars.

During the 7 March 1970 total solar eclipse, steps were taken to overcome both drawbacks. Multiple photographic sites were established along the path of totality. This should provide data correlation if, indeed, the images represent real objects. To further differentiate the non-stellar images on the plates from spurious images or plate defects a narrow-band, scanning photometer of exceptional sensitivity was designed. This unit was rushed from drawing board to operational hardware in the three months preceding the 1968 eclipse. Although the photometer, itself, appeared to function properly during the Siberian eclipse poor recording technique made the data unintellegible.

A redesign of the recording system was accomplished for the 1970 total solar eclipse. Operating from a site near Miahuatlán in southwestern Mexico the new photometer performed admirably. The results will be discussed later on.

Design of the Photoelectric Photometer

The photometer (fig. 1) design is based on an unusual transversing slit concept. A 200 mm, single-lens objective of 250 mm focal length, images 9.8 degrees of sky onto the face of an RCA 7326 photomultiplier tube placed just behind the focal plane. At the focal plane is a laterally-driven "V"-shaped slit, with a small deadband at its apex. The mechanical slits, of 3 arcminutes width, are driven across the 43 mm active surface of the PMT by a reversible synchronous motor. Simultaneously recorded are the position of the slit and the anode current output of the PMT. (~~see fig. 2~~).

Reduction of the data, first to tube face coordinates, and ultimately to celestial coordinates, is readily accomplished. On the first scan the light will pass through a sodium D filter before entering the scanning slits, while during the second scan a CN (3883Å) filter will be used.

By the above method we anticipate isolation of both CN and Na emissions at a very high gain. The photometer is designed to record the sodium D lines at an equivalent stellar magnitude of +9 or fainter.

Admittedly the spatial resolution of the photometer is somewhat limited by its slit width of 3 arcminutes. This dimension was selected to obtain the lowest background level and also be compatible with the PMT/amplifier/recorder response times at a slit scanning rate of 0.66 degrees per second, and the anticipated off-axis coma to be suffered by the image. It is to be noted that the subject photometer design tolerates smeared images well, since we only are interested in recording the total energy contained within an image, and not its degree of sharpness. A block diagram of the slit drive is shown in Fig. 2.

Limiting Magnitude of the Scanning Photometer

To determine the current from the photomultiplier tube as a function of magnitude for solar-proximate comets, we must evaluate each of the following and calculate the product of:

(i) the intensity in the Na lines and the CN band at the top of the atmosphere for a representative solar-proximate comet,

(ii) the atmospheric transmission,

(iii) the area of the objective (324 cm^2),

(iv) the transmission of the optical system,

(v) the radiant sensitivity of the PMT,

(vi) the relative response of the surface of the PMT at the appropriate wavelength.

A. Energy from the Source (at top of atmosphere)

If an object has the same emission spectrum as the sun but is 35 magnitudes fainter (at +8.3), then the energy per second per cm^2 reaching the atmosphere is 0.139×10^{-14} w/cm^2. (The value 0.139 w/cm^2 is simply the solar constant).

For a solar proximate comet, however, the emission occurs predominantly in the Na lines and CN band. If we assume that 40% of the total cometary emission falls within the limits of each of the two filters selected, then for a comet of magnitude +8.3:

$$\left.\begin{array}{l}\text{intensity (in each the}\\ \text{Na lines and CN band)}\\ \text{at top of atmosphere}\end{array}\right\} = 0.056 \times 10^{-14} \ w/cm^2$$

In the above calculation, if we should use a value of 16% rather than the 40% figure for the energy in each band, the final results would be shifted by one magnitude. The limit of cometary detection would be equivalent to stellar magnitude +8.8 rather than + 9.8. Figure 3 should then be shifted accordingly by one magnitude. Since the noise considerations are unaffected by this energy percentage in either band, this would result in a +8.8 magnitude limitation, or approximately +9 as mentioned previously.

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B. Atmospheric Transmission

As an example we shall consider a solar zenith angle Θ as 72 degrees. For this large value of Θ it is essential not only to determine the atmospheric transmission as a function of wavelength but also as a function of the solar zenith angle.

Before proceeding further, we shall introduce the following notation. Let

I = intensity of radiation outside the atmosphere
I' = intensity at the surface of the Earth
m = stellar magnitude outside the atmosphere
m' = stellar magnitude at the surface of the Earth

Since the relationship between the change in magnitude to the ratio of intensities is well known, we may write (ref. 5):

$$\frac{I}{I'} = 2.51^{m' - m} \tag{1}$$

For radiation traveling through a medium, it may be assumed that the absorption and scattering results in a final intensity given by

$$I' = Ie^{-\mu x} \tag{2}$$

where x is the distance traveled through the medium (atmosphere).*

Taking logarithms of equations (1) and (2) and writing x as a function of the zenith angle, we have

$$\begin{aligned} \ln (I/I')_\theta &= \{\ln (I/I')_o\} \sec \theta \\ &= (m' - m)_\theta \ln 2.51 \end{aligned} \tag{3}$$

where the subscripts $\underline{\theta}$ and $\underline{o}$ denote the expressions are to be evaluated at the angles $\underline{\theta}$ and $\underline{o}$, respectively.

If t and t_o are the atmospheric transmissions at the angles θ and o, respectively, at the wavelength λ, then

$$t = (I/I')_\theta$$

and

$$\ln t = (\ln t_o) \sec \theta = -2.97 \, (m' - m)_o \tag{4}$$

*Although equation (2) is valid only if μ is a constant, a somewhat more sophisticated derivation produces the same equation with μ being replaced by an average or effective absorption coefficient.

Using tabulated values of Δm at various wavelengths, we can easily calculate the atmospheric transmission at the desired angle ($\theta = 72^{o}$).

TABLE 1 - A

λ	$(m' - m)_o$ (ref. 6)	t
3530 Å	0.61	0.16
4220	0.29	0.42
4880	0.18	0.58
5700	0.14	0.66
7190	0.06	0.84

TABLE 2 - B

λ	t (at $\theta = 80^{o}$)(ref, 7)	t (at $\theta = 72^{o}$)
3000	1×10^{-11}	10^{-7}
4000	0.0760	0.23
5000	0.276	0.49
6000	0.382	0.58
7000	0.600	0.75
8000	0.698	0.82

From a plot of t versus λ (see fig. 4), we have determined the transmission coefficients of the CN bands and Na lines and tabulated them below:

TABLE 11

Band Designation	Approximate Wavelength	Atmospheric Transmission
CN	3883 Å	$t = 0.22 \pm 0.06$
Na	5890/5896	$t = 0.62 \pm 0.10$

C. Optical System Transmission

The values listed are those taken as representative of the various components as supplied by the manufacturers.

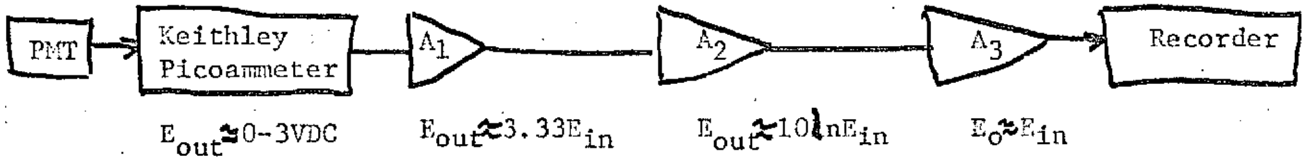
1. single element objective 0.92
2. sodium filter 0.80
   Net transmission (Na) 0.73
3. cyanogen filter 0.50
   Net transmission (CN) 0.46

Signal Recording Technique

The output of the photomultiplier tube is recorded on a strip chart from which co-ordinate and amplitude can be derived.

I Recording System Description

Shown below is a block diagram of the signal conditioning used to record the output of the scanned photomultiplier tube.



The output of the photomultiplier tube is fed directly to a Keithley Model 417 picoammeter which provides adjustable noise supression (for negation of the tube dark current), range adjustment, visual display and a 0-3VDC output signal corresponding to full scale of the range setting.

The 0-3VDC Keithley output is then fed to a three stage amplifier whose specific purpose is to provide log supression and a line driver for the strip chart recorder. The first stage amplifies the 0-3VDC output to the 0-10VDC required for the full excursion of the log amplifier. A_2; the log amplifier is provided to increase the dynamic range of the recorder and provides a 0-20 VDC output capability corresponding to 10 ln of E_{in}. A_3 has a gain of one and its utility is primarily to drive low sensitivity recorders. This affords the flexibility of either driving a strip chart recorder with internal amplifiers, or driving an optical galvanometer recorder where high frequency response is desired. The latter may be used for short duration events where high scan rates of the photometer traversing slit are required.

II Recording System Operation

Prior to utilizing the photometer and recorder to obtain actual data a system calibration is required. To calibrate the system one may neglect the individual component inaccuracies by performing an end to end calibration. That is, stimulating the photometer optically and plotting the optical stimulation from the output of the photomultiplier tube vs. the recorded voltage. Optical stimulation for an end to end calibration is best provided by a collimated adjustable point source which permits a full magnitude calibration curve to be generated. The panel meter on the front of the Keithley provides a reference for the photomultiplier input points on the calibration curve. Once the initial calibration curve is generated from a star simulator (secondary standard) the next step is to observe actual stellar sources. Final calibration then proceeds in the usual manner, i.e. atmospheric absorption for the star's elevation angle is computed out and the relative spectral response of the PMT/optics is mathematically folded against the stellar profile to reduce the photometer sensitivity to a workable visual magnitude scale.

D. Photomultiplier tube characteristics

For the PMT 7326 the radiant sensitivity at 4200 Å is 9,600 μa/μw (median value (ref. 8) and the relative response of the S-20 surface is 0.50 at 5890 Å and 0.95 at 3883 Å.

E. PMT anode current

From the considerations listed above we can calculate the power input to the photomultiplier tube for a comet of equivalent stellar magnitude +8.3. For this magnitude we find the PMT output to be 0.40 nanoamp for the Na lines and 0.16 nanoamps for the CN band

Using equation (1) or (3) we can easily calculate the intensity and anode current as a function of the magnitude; these are tabulated in Table 111 and shown in Figure 3.

TABLE 111

Equivalent Stellar Magnitude	PMT Anode Current (Nano amps) - Na Filter	CN Filter
+6.0	3.4	1.35
+7.0	1.3	0.54
+8.0	0.54	0.21
+9.0	0.22	0.09

Note: Values are derived for PMT at 1800 volts. Increasing operating voltage to 2000 V. increases sensitivity by approximately 250% (RCA data), thereby making the system one stellar magnitude more sensitive. The optimum signal to noise ratio at these magnitudes will be investigated further.

Signal to Noise Considerations

A. Noise from external sources

Three ~~Two~~ external sources of background noise which must be considered are:

1.) the intrinsic brightness of the corona
2.) the atmospheric airglow
3.) the sky beyond

Taking the brightness ~~of~~ the solar corona during total eclipse as 1.6 x 10^{-9} times that of the mean sun (ref. 9) and the diameter of the corona as 2 degrees, we calculate the maximum rate at which radiation is impinging on the photomultiplier tube to be equivalent to that from a -1.0 visual magnitude source, where the slit dimensions are 3 arc minutes by 10 degrees.

If we are to achieve cometary detection at an equivalent magnitude of +9, we must contend with a signal to background ratio of 1:10^4! However, with the narrow band filtering to be utilized this ratio is immediately reduced to approximately 1:200. This does not preclude the attaining of the aforementioned goals and is discussed in section B below.

The night sky airglow approximates the equivalent of 200 10th magnitude sources per square degree or about +4.3 stellar magnitude per square degree at the zenith. Since the slit system will see only 0.5 square degree and narrow band filters are being employed, the night time airglow input corresponds to approximately +9.3 stellar magnitude.

The increase in the radiation level, above that for the night sky, of the observed sky area - within 5^{o} of the sun during the total solar eclipse - is difficult to estimate. If we assume that the airglow during the total solar eclipse is 100 times greater than that from the night sky, the input intensity would correspond to approximately +4 stellar magnitude; then a comet at an equivalent magnitude of +9 signal to background ratio would be 1:100. (This ratio is the inverse of the multiplicative factor of airglow increase; i.e. had we assumed that the airglow during the eclipse was 50 times that of the night sky, the signal to background ratio would be 1:50.)

This background may be eliminated as indicated in section B.

B. Elimination of background noise

The signal to background ratio, although it is extremely poor as given above, can be overcome by the following two procedures:

1) the incorporation of occulting features of a Solar coronagraph (Lyot-type spots) on both filters and PMT face-should practically eliminate the radiation corona; these spots were selected to occult a 2 degree disk.
2) the incorporation of the Keithley picoammeter, model 417, with the suppression current feature, permits the bucking out of the background and measuring signals equivalent to +9th magnitude.

This second consideration should be effective in reducing the background only from airglow as that from the corona is variable-due to slit movement-and must be eliminated by the first consideration.

Now the actual noise or fluctuation in the current due to the radiation coming from the airglow may be more critical; it can be estimated using statistical considerations. This results in

$$\frac{\Delta I}{I} \approx \frac{\Delta N}{N} \sim \frac{\sqrt{N}}{N}$$

as an ideal lower noise limit due to airglow, where I is the current and N is the number of photons per second entering the PMT from the airglow. A somewhat simplified treatment results in $N \approx 10^{8}$ photons/sec entering the PMT where we have used the previous figure for the eclipse airglow of +4 magnitude. Then

$$\frac{\Delta I}{I} \sim 10^{-4}$$

For the figures used, this corresponds to a noise level of approximately 2×10^{-12} ampere.

Although this is by no means a precise figure, what it does imply is that if we buck out the background current due to airglow and introduce the coronagraph modifications, we may be able to detect comets with an equivalent magnitude of +9.

Experimental Results

The new photometer operated satisfactorily during the 1970 total solar eclipse. Data reduction has been completed but interpretation of the photometric data must await reduction and analysis of the photographic plates which were taken during the event. Such correlation becomes mandatory since certain ambiguities in the photometric data preclude singular reduction to a unique set of coordinates. If we consider more than one object lying along each of the scanning slits simultaneously, several possible spatial solutions become apparent. This is the case to date with the Mexican eclipse data. Hopefully, comparison with the white light photographic plates will suggest a unique solution for each image. Figure 5 is the data from 7 March. Each major deflection represents transit of an individual slit across the PMT. Note that no effort was made to supress the total sky background, except for a logarithmic compression. The gross shape of the data sweeps is directly related to two factors: actual sky brightness (probably continuum leaking through our filters), and the geometry of a linear slit traversing a circular PMT face, thereby "seeing" chords of increasing and then decreasing lengths. The latter explanation is believed to account for most of the deflection.

Actual data points may be seen as ripples along both ascending and descending slopes of the sweeps. A series of observations of comet Bennet (1969i) during the month of April 1970 have enabled us to differentiate systematic noise from true signal when interpreting the older data.

Although the data analysis is several months from completion we believe that the instrument has lived up to design expectations and foresee potential future use not only during solar eclipse but as a regular sky patrol instrument.

References

1) F. Dossin, Comptes Rendus <u>257</u>, 2246 (Oct. 1963)

2) Courten and Genberg, Astronomical Journal, 1352 (Sept. 1967)

3) Courten et al, Bulletin A.A.S., Vol. 1, No. 4, 1969

4) The design of this instrument was supported in part under NASA grants NGR 33-001-019 and NGR 33-018-001 and NSF grants GA 10618 and GA 16434

5) Mehlin, Astronomy

6) Blanco and M. Cuskey, Basic Physics

7) Perkin-Elmer Corporation, Report No. 7846

8) RCA Electron Tube Division Data Handbook, February 1959

9) C. W. Allen, Astrophysical Qualities (Athlone Press, London 1963)

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APPENDIX II

SUMMARY PAPER ON

COMET SEARCHES DURING

FOUR MAJOR ECLIPSES

Henry C. Courten

September 1971

ABSTRACT

Photographic observations made during the solar eclipses of 1963, 1966, 1968 and 1970 indicate the presence of previously unidentified celestial objects in the near-angular vicinity of the sun. Observational data and equipment are described. Possible origins of the "objects" are enumerated, as well as suggested future experiments to confirm the results.

Beginning with the total solar eclipse of 1963 a series of concerted efforts have been made to identify small objects thought to be comets in the near vicinity of the sun. The first major effort by Donn and Dossin(*) appeared to be somewhat successful in that a comet-like image appeared on multiple photographic plates at twenty solar radii.

In 1966 we photographed the total solar eclipse from southern Brazil with three broadband-filtered 305 mm cameras and a 1200 mm camera operating in white light.

The estimated equivalent visual magnitude of the objects is from +7 to +9. Stellar images to +12 were found.

Preliminary results indicated the possible presence of ten "cometary" images(**). Subsequent measurement and reduction by Mihran Miranian, using a high precision Mann Comparator, reduced the number of coincident, non-stellar images appearing on five photographic plates to a single object at the following celestial coordinates (epoch 1950):

$$15^{H} \quad 9.4^{M} \pm 0.1^{M}$$

$$-16^{\circ} \quad 02' \pm 1'$$

This sighting is in remarkably good agreement with an airborne observation made over the Atlantic off the southern

(*) F. Dossin, Comptes Rendus 257, 2246 (Oct. 1963)
(**) H. Courten and R. Genberg, A.J. 72, 791, 1967

coast of Brazil during the same eclipse by Sheldon Smith(*). The coordinates of the object observed by Smith are:

$$15^{H} \quad 9.3^{M}$$

$$-16^{o} \quad 07'$$

In 1968 observations were made from Siberia near the town of Yurgomysh. Using our earlier, rather unsophisticated measuring technique we "found" nine interesting non-stellar images(**). The absence of another observation site during this eclipse makes the data inconclusive.

The 1970 expedition, sponsored by Dowling College, Oakdale, New York, monitored the solar eclipse from Miahuatlan, Mexico, using two 1000 mm cameras and a broadfield, scanning-slit photometer designed to detect cometary spectral emissions at 388.3 and 589-589.6 millimicrons (mμ). Cooperating with us was a two man team (Cafiero and Dunayer) at a site near Elizabethtown, North Carolina. The latter site was equipped with a 1200 mm camera.

Twenty non-stellar "objects" were measured on the 1970 Mexican plates. Fourteen appeared on all five plates. Of the remaining six, two appeared on the same four plates, the other four were scattered, but appeared on only two plates.

(*) Private communication from Sheldon Smith, NASA Ames Research Laboratory
(**) H. C. Courten et al, AAS Bull. 1, 338, 1969

Thirty-six, non-stellar "objects" were measured on the 1970 North Carolina plates. Thirty appeared on all five plates. The remaining six appeared on four plates, although not necessarily the same ones.

Estimated equivalent visual magnitude was the same as in 1966 (+7 to +9). Stellar images to +9.5 were found.

Reduction of the 1970 plates by Miranian revealed five non-stellar images on five of the Mexican plates which apparently match images on each of five North Carolina plates. The celestial coordinates of these interesting objects are shown on Table I.

Rather large positional residuals of approximately one arcminute were noted not only among the "objects" but also among the background stars on individual plates, even when using a ten-star reduction program. A review of both the 1966 and 1970 data indicates that the residuals increase to a maximum at the center of totality and then return to approximately the same baseline at the end of totality. Possible correlation of these data with atmospheric turbulence in the shadow cone will be investigated more quantitatively during future eclipses.

A third observation station site at Hampton, Virginia, manned by Sheldon Smith using a 40 cm NASA telescope with 70 mm film, has yielded a confirmatory image for our Mexico #3 : North Carolina #35 pair. Smith's coordinates are:

23^{H} 8.2^{M}

-6^{o} $13'$

Significantly, this appears to match our brightest pair of objects.

Taking into consideration only the 1970 data, an attempt has been made to ascertain the probability that we have found real objects in space, rather than plate artifacts which are common when searching for images just a little above emulsion grain size. Table II illustrates some of the factors used in arriving at our high degree of confidence.

Because of the manner in which the data was reduced, only three plates from each site were factored into the probability computation. In actuality the objects appear on five plates from each station. During the initial search three plates from a given station were scanned completely independently of each other. All of the artifacts noted on the three were then cross-checked for coincidence with the remaining two plates. Hence, coincidence on the latter plates were too prone to subjective interpretation to be considered in our probability estimate.

The addition of a third, and completely independent, verification for one of our pairs of objects by Smith makes the probability that this object exists in reality very high.

Three possible interpretations appear consistent with the observational data:

1. the images are of an earlier comet(s).
2. an intramercurial planet(s), or perhaps another asteroid belt, has been found.
3. we are viewing interstellar matter falling into the sun.

Our scanning-slit photometer did not record the presence of signal at either the bright cyanogen band (388.3 mμ), or the sodium "D" lines (589 - 589.6 mμ). The instrument was designed to record a CN - bright comet to a limiting equivalent visual magnitude of +9, and a Na - bright comet to +10. Apparently there was either no cometary emission at these wavelengths during the 1970 event, or the instrument malfunctioned.

A comet at 0.1 AU would require a head on the order of 40 km in diameter to be observed from Earth if its output were only that of reflected sunlight. One might then argue that a comet of such extraordinary dimension would likely produce a tail structure which would have been detected simultaneously by other observers in either the dawn or evening sky. Such a comet was not observed near the eclipse date.

While our data is positive, it does lack sufficient substance for an absolute claim. Rather, our findings indicate the need for a more extensive search during the next several eclipses as well as a thorough search for existing eclipse plates which may contain corroborating data.

Several avenues suggest themselves for obtaining confirmatory data in the future:

1. Secure both white light and spectrally filtered high resolution photographic plates from a number of sites (ground and airborne) separated in time and location.

2. Continue photometric searches with a view toward spectial analyses of the "objects".
3. Extend the search into the near infrared.
4. Observe the near-vicinity of the sun with a spaceborne broadfield coronagraph.
5. Actively scan the prescribed area with radio telescopes.

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Acknowledgements:

1. I thank Messrs. Lawrence Cafiero and Harold Dunayer, formerly of the Gruman Aerospace Corp., for successful operation of the North Carolina site in 1970; Dr. Richard Genberg, of Adelphi University, and Dr. Herbert Ogden for their participation in the 1966 effort in Brazil; Mr. Mihran Miranian for measuring and reducing the photographic plates from both eclipses in addition to participating in the Mexican expedition; and Mr. Joseph Rothenberg, of the Grumman Aerospace Corp., for designing the electronics for our photometric recordings.

   I thank Dr. Bertram Donn of the Goddard Space Flight Center for his assistance and advice in carrying out the expeditions of 1966 through 1970.

2. The 1966 eclipse expedition was funded in part by the National Aeronautics and Space Administration.

   The 1968 and 1970 efforts were funded in part by the National Science Foundation and NASA.

TABLE I

COORDINATES OF INTERESTING PAIRS OF OBJECTS

Note: Motions have been adjusted to compensate for the Earth's orbital motion between Mexico and North Carolina. (One hour between observations.)

Object Number	Location*	1950 Epoch		δ		ΔαCosδ	Δδ	Total Motion
3.	M	23^h	$7^m.5$	-6^o	19'			
35.	NC	23	8.6	-6	21	+14'	-3'	14'
Smith		23	8.2	-6	13			
4.	M	23	9.8	-4	31	-8	+2	8
8.	NC	23	9.5	-4	28			
4.	M	23	9.8	-4	31	-2	-2	3
9.	NC	23	9.9	-4	32			
8.	M	23	11.6	-3	09	-4	+6	7
12.	NC	23	11.5	-3	02			
8.	M	23	11.6	-3	09	+1	0	1
13.	NC	23	11.8	-3	08			
9.	M	23	12.2	-3	09	-13	+6	14
12.	NC	23	11.5	-3	02			
9.	M	23	12.2	-3	09	-8	0	8
13.	NC	23	11.8	-3	08			
14.	M	23	17.0	-6	22	-14	-2	14
27.	NC	23	16.2	-6	23			
Solar Motion Adjustment						-2	-1	2

*M = Mexico NC = North Carolina

TABLE II

FACTORS RELATING TO PROBABILITY OF PLATE ARTIFACTS BEING REAL

• Carefully scrutinized plate area	225 cm^2
• Average number of initial artifacts	300
• Approximate number of stars in field	100 (to +9.5)
• Artificially circled area around each artifact	20.2 mm^2
• Assume only 200 total artifacts	(subtract 100 stars)
• Plate 1 matches with Plate 2	49 pairs
• Probability that pairs are coincidental	.2
• Plate 1 matches with Plate 3	17 pairs
• Probability that pairs are coincidental	2×10^{-2}
• Plate 2 matches with Plate 3	9 pairs
• Probability that pairs are coincidental	10^{-3}
• Three plates from one station compared to second station yields a probability that seven (7) pairs between stations are coincidental	10^{-6}
• Coincidence of one of the seven pairs with an independent third station adjusts the probability to 10^{-12}	