Journal of Scientific Exploration, Vol. 9, No. 1, pp. 45–63, 1995 0892-3310/95

Digital Video Analysis Of Anomalous Space Objects

MARK J. CARLOTTO

5 *Ryans* Place, *Beverly, MA 01915*

Abstract — Video data showing multiple objects moving in unusual trajectories in space is examined. The video was captured by a camera aboard the Space Shuttle Discovery (mission STS-48) between 20:30 and 20:45 GMT on 15 September 1991 near the west coast of Australia. Digital video analysis is performed to determine if the objects in question are ice particles disturbed by a thruster firing as contended by NASA or other objects moving independently of the shuttle. Results of our analysis show that it is unlikely that a thruster firing occurred since the attitude of the spacecraft does not change. Our analysis indicates that there are two groups of correlated object motions. One group changes direction at the time of a flash, claimed by NASA to be due to a thruster firing. The other group changes direction 1.5 seconds later. Assuming the objects are roughly the same size, brightness measurements of the objects as they pass over the airglow layer near the limb suggest that the objects in the first group are farther away yet they change direction first. This behavior is inconsistent with the thruster firing hypothesis. For one of the objects known as the "target", it is shown that the only hypothesis that is consistent with the data is that the object is at or near the physical horizon. We go on to show that several other objects in the video are clearly moving in circular arcs and are thus likely to be relatively far away from the shuttle. The estimated speed of one of these objects, about 35 km/sec, is approximately the same as that of the target if we assume that it is at the physical horizon. At the end of the event, the shuttle's camera pans down to reveal a number of objects moving below the shuttle. One of the objects appears to have a definite structure consisting of three lobes arranged in a triangular pattern.

1. Introduction

On September 15, 1991, live video showing multiple objects moving in unusual trajectories was captured by cameras aboard the Space Shuttle Discovery (STS-48). The video, which was being broadcast over NASA Select TV, was recorded by Mr. Donald Ratsch. Mr. Ratsch observed what he believed to be four anomalous events. One of those events was recorded by a camera in the shuttle's payload bay between 20:30 and 20:45 GMT near the west coast of Australia. The event involves perhaps as many as a dozen objects moving in different directions relative to the spacecraft. One of the objects appears at a point near the horizon and moves in a path that seems to follow the horizon. After a flash, the object abruptly changes direction and speed. This is followed a few seconds later by a streak that moves rapidly across the field of view and crosses the path of the object. At the end of the event. the camera pitches down to reveal several objects moving below the shuttle. One of the objects has a triangular shape.

Within days Mr. Ratsch provided copies of his original recording along with detailed descriptions of four anomalous events to various investigators including NASA. Two months later after reviewing the video, NASA agreed with his descriptions of the events but disagreed with his interpretations (i.e., that they were UFOs). NASA concluded the objects seen in the video were either ice particles or orbiter-generated debris illuminated by sunlight[1]. Concerning the event considered in this paper they stated:

"The objects seen are orbiter-generated debris illuminated by the sun. The flicker of light is the result of firing of the attitude thrusters on the orbiter, and the abrupt motions of the particles result from the impact of gas jets from the thrusters."

The purpose of this paper is to examine this event in detail in order to determine if the objects in question are indeed debris in close proximity to the shuttle disturbed by a thruster firing as contended by NASA or more distant objects moving independently of the shuttle. After providing additional background information in Section 2, the motions of all key objects are examined in Section 3. The remaining sections focus on specific objects and phenomena observed during the event. Section 4 analyzes the trajectory and brightness of one of the objects (the "target") in detail. Section 5 focuses on several objects on the other side of the frame, including a very bright pulsating object, which appear to move in circular paths. An enlargement of a triangular-shaped object traveling below the shuttle is also presented in Section 5. Section 6 summarizes our findings and suggests future work.

2. Background

STS-48 was the 43rd shuttle mission and the 13th flight of Discovery. The crew was John Creighton, Ken Reightler, Jim Buchli, Mark Brown, and Sam Gemar. STS-48 was launched from the Kennedy Space Center on September 12 and landed at Edwards Air Force Base on September 18, 1991. The shuttle's orbit was inclined 57 degrees to the equator. Its altitude was about 570 km with an orbital period of 96.1 minutes.

The event considered in this paper occurred when the shuttle was passing near the western coast of Australia . The approximate location of the event is indicated in Figure 1 and occurred between 20:30-20:45 GMT. (We note that Mr. Ratsch recorded another anomalous event not considered in this paper one orbit earlier in approximately the same location.) At this point in the mission, Discovery was traveling in a southeasterly direction in darkness, nearing the day-night terminator as shown in Figure 2. Flying "belly-first", one of the

[1]Letter dated 22 November 1991 to Representative Helen Delich Bentley from Martin P. Kress, Assistant Administrator for Legislative Affairs, NASA.

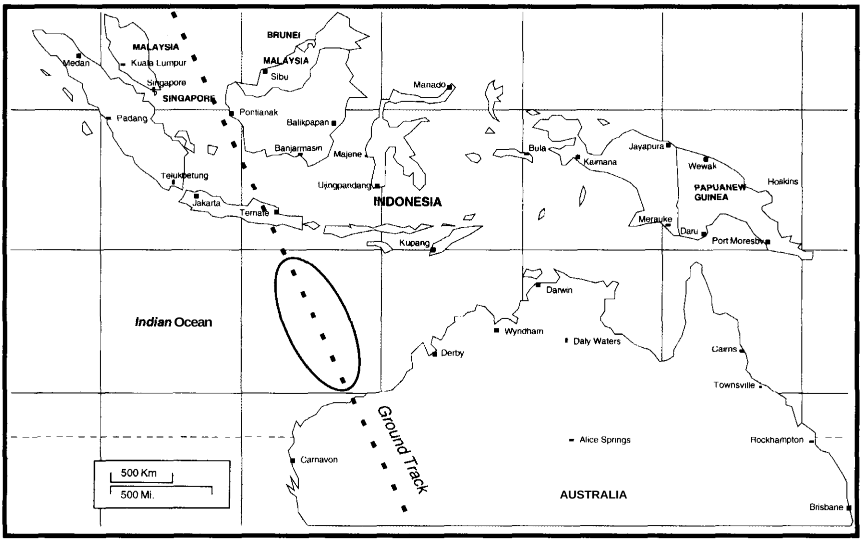


Fig. 1. Approximate location of event.

cameras in the payload bay was looking back toward the earth and the horizon; the sun was beginning to rise towards the right.

To more precisely define the attitude of the shuttle during the event, video key frames prior to the event were digitized from the video data. Stars visible in these key frames were extracted and assembled into an image strip and identified using a star chart. The image strip and star chart are shown in Figure 3. The two most prominent stars seen during the event are Errai and Polaris (designated M2 and M3 in the next section) with apparent magnitudes of 3.21 and 2.02. The angular separation between Polaris and the Sun is approximately 87°

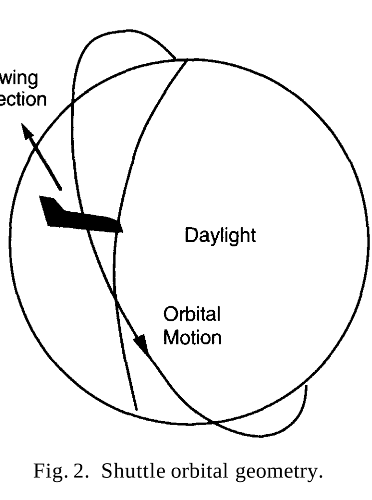


Fig. 2. Shuttle orbital geometry.

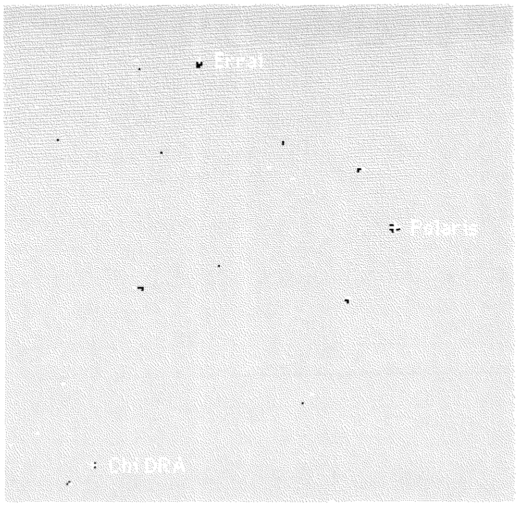


Fig. 3 Star chart (white) overlaid on stars from shuttle video (black) with gray background

(Figure 4). We are thus able to verify that the shuttle's camera is in fact looking north with Polaris and Errai within the field of view arid the sun rising to the right of the camera.

'The event was recorded by Mr. Ratsch in VHS format. Our analysis was performed on digitized portions of a first-generation VHS copy of his original recording In most cases the objects of interest are only a few pixels in size so it is not possible to resolve their actual spatial extent. Brightness values were scaled to 8 bits ($0 \le DN < 256$) with the brightest pixels kept well below saturation ($DN=255$)

3. Trajectory Analysis

First we captured the overall event in 51 key frames, digitized one second apart. Since the shuttle had just moved into sunlight, the full video frame (640x480) was cropped to 480x480 pixels to eliminate lens flare from the sun

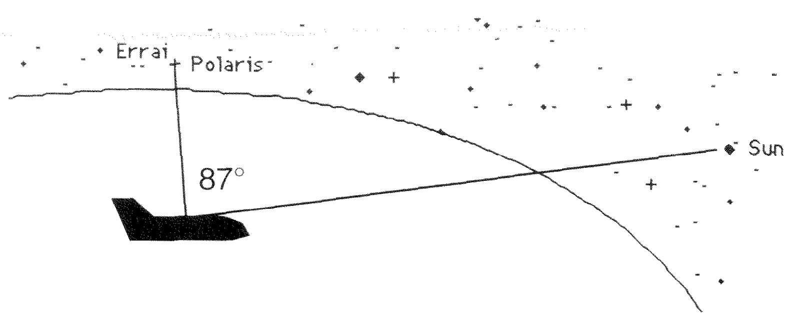


Fig. 4 Relation between Shuttle, Polaris, and Sun

reflected on the left side of the frame. Figure 5 summarizes the overall sequence in the form of an unfolded volume. The x-y plane shows a time average of the object motions over the full 51 seconds; the x-z and y-z planes show cross-sections of the motions over time. Key objects are denoted M0-M9. The location of the flash in time is also noted in the figure. Objects M2 and M3 are setting stars (Errai and Polaris). Over the 51 second sequence, M2 and M3 move 3.18 degree\. Their measured displacement in the video frame was 49 pixels which yields a scale factor of 0.065 degrees/pixel. The field of view shown in Figure 5 is thus approximately 31 degrees in size.

Figure 6a plots the 2-D motions of all 10 objects derived from the 51 frames. Object location\ were manually extracted from each digitized frame. The general direction of motion of each object is indicated in Figure 6b.

Figure 7a shows the direction of motion in the viewing plane of two objects (M0 and M1) that appear to change direction as the same time. Directions are in the range 0 to 2π radians where 0, $\pi/2$, π, and $3\pi/2$ radians are to the left, down, to the right. and up, respectively. In Figure 7b the direction of motion of M4-M7 are overlaid on those of M0 and M1. We note that M4-M7 appear. as a group, to change direction about 1.5 seconds after MO and M1. Objects M2, M3, M8 and M9 do not appear to change direction in Fig 6 and are thus not

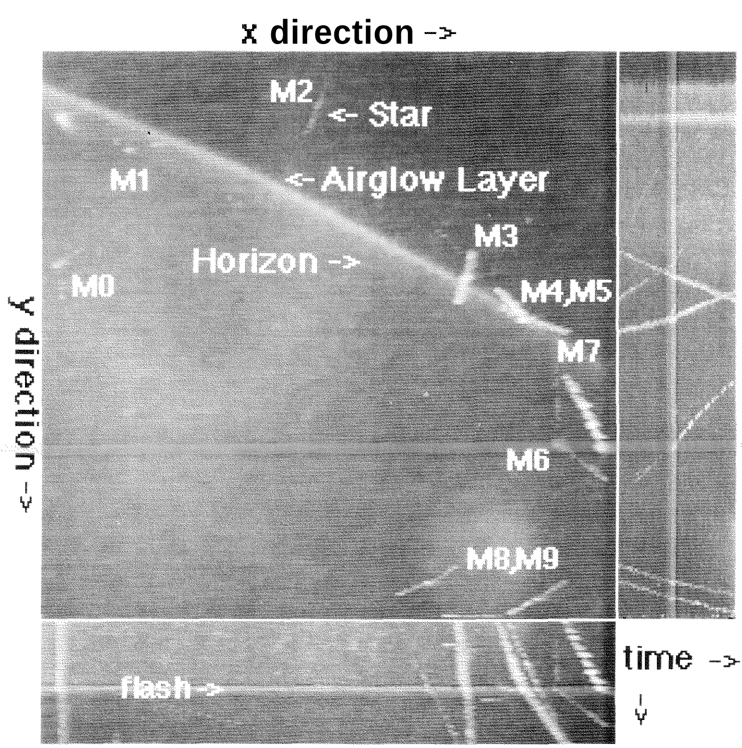
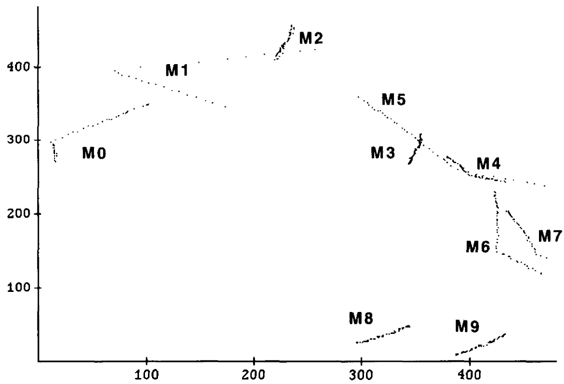
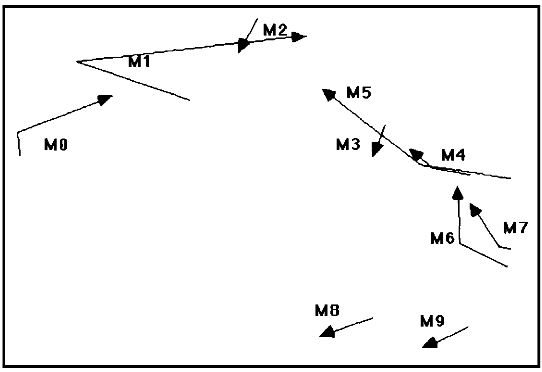


Fig. 5. Overview of event presented as "Unfolded Volume."



(6a)



(6b)

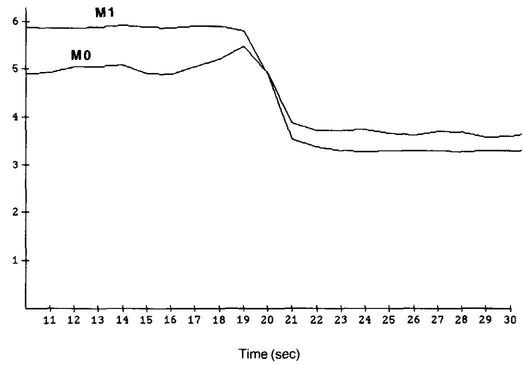
Fig. 6. Summary of 2-D object motions.

shown in Figure 7. M2 and M3 are setting stars as noted above; M8 and M9 are moving towards the shuttle but cannot be lights on the earth's surface. (Since the camera is looking back, lights on the surface would move away from the shuttle toward the horizon.)

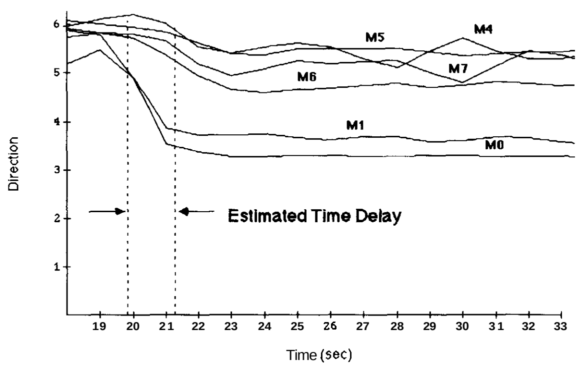
NASA's explanation is that the observed flash is the firing of an attitude control thruster whose exhaust gases subsequently altered the trajectory of particles floating near the shuttle. There are three groups of thrusters on the orbiter: in the left- and right-hand Orbital Maneuvering System/Reaction Control System (OMS/RCS) pods on the aft fuselage and in the forward fuselage[2]. The RCS provides thrust for velocity changes and attitude control. Each of the aft RCS pods has 12 primary and 2 vernier engines with 870 and 25 lbs. of thrust

---

[2] **S. Z. Rubenstein, "Space shuttle orbiter," in *Space Shuttle: Dawn of an Era, (AAS 79-271) Proceedings of the 26th American Astronautical Society Annual Conference,* November *1979,* Los Angeles.**



(7a)



(7b)

Fig. 7. Correlated 2D object motions.

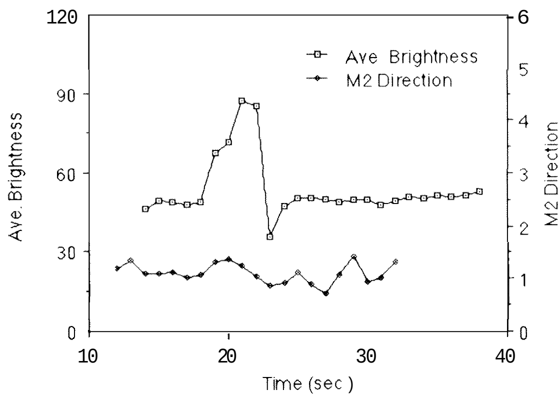
respectively. The verniers burn either in 80 millisecond pulses or continuously from 1 to **125** seconds. The main thrusters fire in 80 ms pulses only.

Figure 8a plots the average brightness of the video frame as a function of time along with the direction of motion of one of the stars M2. (A plot of the frame brightness and the motion of M1 is shown in Figure 8b for reference.) Following the jump in brightness, purportedly due to the thruster firing, there is no detectable change in the direction of M2. Yet the apparent motion of all objects including **M2** must change if the attitude of the spacecraft was altered by the thruster firing. Figure 8c shows seven frames spaced 1 second apart between t= **19** and t= **25** seconds. From the length of the brightening observed in the video it is likely that the thruster in question is probably one of the verniers located in the aft OMS/RCS pod to the left of the camera. According to Oberg[3]

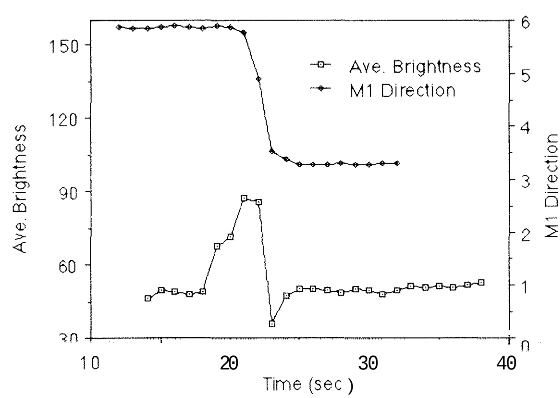
---

[3]Letter **dated 23 November 1992 to Erik Beckjordan from James Oberg. Courtesy copy sent to Dan Ratsch.**

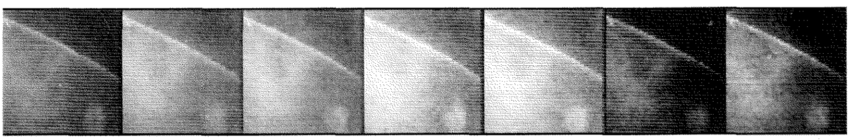
the angular rates induced by the primary thrusters are between are 0.05 and 0.1 deg/sec.) An 80 ms burn of the vernier thruster would cause a much smaller motion, between 0.0014 and 0.0029 deg/sec. However the length of the flash indicate\ a longer burn. If we assume the vernier thruster fired for 1 second (conservative). the angular rate would be between 0.0175 and 0.0363 deg/sec. Ten seconds after the thruster firing, the attitude would change by 0.175 to 0.363 deg, or 2 to 6 pixels which should be easily detectable either in a deflec-



(8a)



(8b)



(8c)

Fig. 8. Frame brightness during thruster firing.

tion in the apparent motion of the stars or a shift of the location of the horizon. The lack of any deflection in star motion or change in the location of the horizon line suggests that the flash was not caused by a thruster firing.

4. Analysis Of Object M1

The most interesting object is M1 which appears at a point just below the horizon. It then moves along a line parallel to and just below the horizon. Prior to the flash mentioned earlier, the object slows and seems to stop. After the flash it changes direction, accelerates and moves across the airglow layer. Shortly thereafter, a streak crosses the object's trajectory as it continues into space. The streak, which is somewhat difficult to see in the video, has been interpreted by Hoagland[4] as a discharge from a kinetic energy weapon aimed at M1 — As a result M1 has been called the "target". Hoagland also speculates that the flash is an electro-magnetic pulse effect induced in the camera by the weapon.

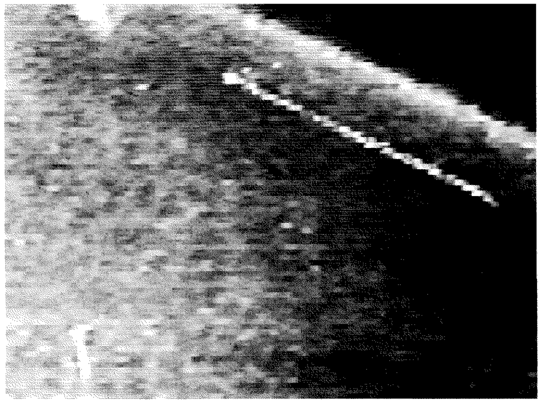
Figure 9 shows time exposures computed from a sequence of images of M1 as it moves along the horizon. Figure 9a is the maximum pixel brightness across the sequence and clearly shows the object appearing at a point just below the horizon line and moving in a path that follows the curve of the earth. Figure 9b is the average brightness for a subset of images in the beginning of the previous sequence. This second figure more clearly delineates the boundaries between the earth, atmosphere, and airglow layers, and better shows the object appearing and moving below the horizon.

A slight tail at the beginning of the track (Figure 9a) suggests that the object may be moving up and out of the atmosphere. This hypothesis is consistent with measurements of the M1's brightness. Figure 10 shows the brightness of M1 at the point where it appears. Instead of changing abruptly as one would expect of an ice particle near the shuttle passing from shadow into sunlight, the brightness increases gradually over a 1 second period. M1's brightness then remains relatively constant as it moves along the horizon line. We also note that there is a lack of significant variations in brightness (with the exception of random measurement errors). Large fluctuations in brightness are typically observed over time when viewing ice or other rotating particles reflecting sunlight as discussed later in the paper.

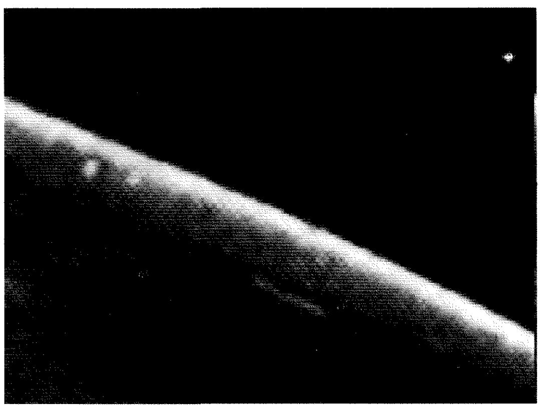
Figure 11 is another time-exposure that shows M1 beginning approximately 2/3 seconds after the flash, after it has changed direction. The dashed line is M1 captured in 1/3 second intervals as it moves across the limb and atmosphere into space. The fainter line is the streak mentioned earlier that quickly moves from the bottom to the top of the image. It appears about 3 seconds later crossing the path of M1.

After M1 changes direction and accelerates, it decreases in brightness. Figure 12a plots the distance in pixels of M1 from the point where it changes

[4]R. C. Hoagland, *The Discovery Space Shuttle Video*, B.C. Video Inc., New York, 1992.



(9a)



(9b)

Fig. 9. M1 track along the horizon.

direction and accelerates. This distance appears to increase at a constant rate. If' the object is moving in a straight line, the lateral distance measured in the image plane is proportional to the total distance traveled. Since the lateral distance appears to be increasing at a constant rate, we hypothesize that the total distance is increasing at a constant rate as well. If this is true, for an object of constant radiance, the measured irradiance (brightness) should decrease at a rate proportional to the inverse syuare of the distance.

The brightness of M1 as a function of time was estimated as follows. First a series of background measurements across the limb and atmosphere were made along a path parallel to that of M1. These values were then subtracted from the corresponding brightness measurements of M1. For an object of

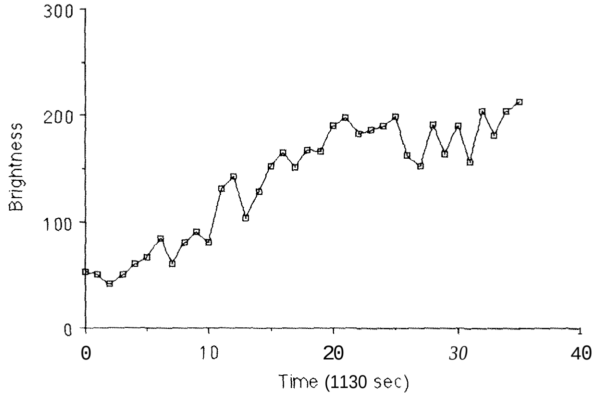


Fig. 10. MI brightness at point of appearance.

constant radiance, the brightness $b=kd^{-2}$ where k is a constant and d is the distance from the object. Let h,,be the initial brightness of an object at a distance d_0 from the observer. This initial distance is unknown. The brightness as a l'unction of time can be written as

$$b(t)^{-1/2} = d(t)k^{1/2} = [d_0 + \Delta d(t)]k^{-1/2}$$

$$b(t)^{-1/2} = b_0^{-1/2} + \Delta d(t)k^{-1/2}$$

where Ad is increase in distance as the object travels from point B to C (Figure 13a). To test if the object is indeed moving away from the observer we plot the measured brightness values raised to the *-1/2* power, $b(t)^{1/2}$, versus the corresponding distances, $\Delta d(t)$ (Figure 12b). The slope is $k^{-1/2}$ and the y-intercept is $b_0^{1/2}$. The measured correlation (0.71) supports our hypothesis at a reasonable

Fig. 11. Time exposure of MI passing across airglow.

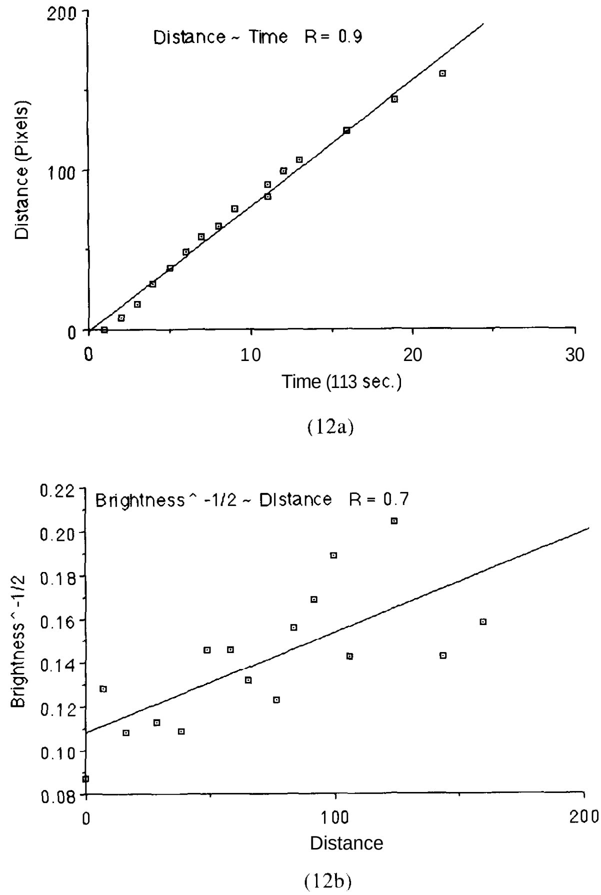
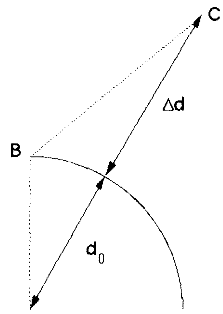


Fig. 12. Position and brightness of M over time.

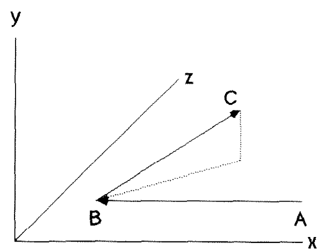
level of confidence that, following the flash, the object moves away from the shuttle at a constant velocity.

The above observations suggest a possible model for the 3-D motion of M1. With reference to Figure 13b, we hypothesize that M1 initially moves at a constant velocity in a plane parallel to the horizon and observer from point A to B. M1 then changes direction and moves away from the observer (point B to C). Since the brightness decreases by a factor of at least 1/2, we conclude that the distance between M1 and the observer increases by a factor of $\sqrt{2}$ or more from point B to C.

The key question is: How far is M1 from the observer? Unfortunately, there is no direct way to determine this distance from the available data. However. M1 must be either 1) near the shuttle, 2) at the physical horizon, or 3) somewhere in between.



(13a)

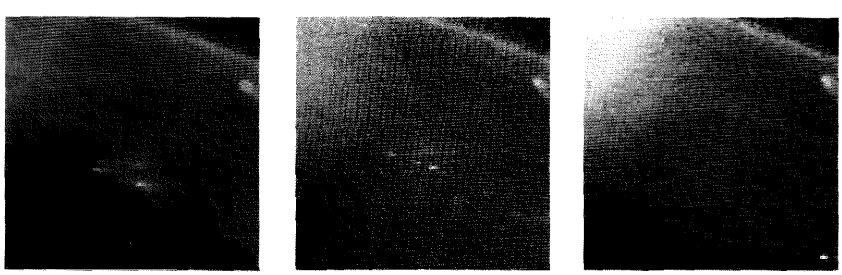


(13b)

Fig. 13. Model for determining 3-D motion.

Figure 14 shows the upper left portion of the video frame before sunrise (a), at sunrise (b), arid 50 seconds later (c). The brightening in the upper left is caused by an increase in scattered light from the right side of the camera lens. Thus when M1 appears in the video, the shuttle is in daylight with the sun to the right. M1 is downtrack from the shuttle and thus cannot be emerging from its shadow. It is thus unlikely that M1 is near the shuttle since there is no mechanism to explain its appearance.

Another possibility is that M1 is farther away, somewhere in between the shuttle and the physical horizon. In the video, M1 appears about 50 seconds after Discovery enters daylight. The terminator is thus below the shuttle and



(a) (b) (c)

Fig. 14. Increase in lens flare at sunrise.

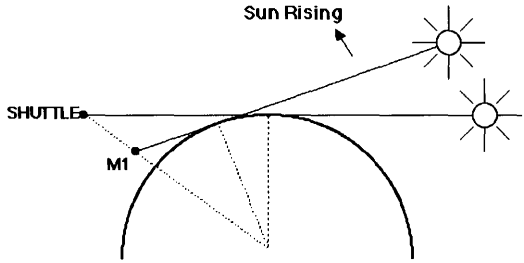


Fig. 15. Geometry for M1 Moving Across Terminator.

moving away. One possible scenario is that M1 moves across the terminator from shadow to light as depicted in Figure 15. The brightness at a point in the image is proportional to the total energy incident on the corresponding detector element. Since the angular extent of M1 is much less than the resolution of the camera, it could appear to increase gradually in brightness as it moves from shadow to light due to a gradually increasing fraction of its surface illuminated by the sun being summed by the detector element. However the object cannot move by more than one pixel over the period of brightening (about 1 second) for this effect to occur. Between points A and B in Figure 13b, M1 moves 66.2 pixels in the video frame over an 8 second period. The lateral velocity, which is relatively constant over this interval, is thus about 8 pixels per second. M1's brightening is inconsistent with this scenario since it is moving too quickly.

This then leaves only one possibility — that M1 is farther away, perhaps at or near the physical horizon. Several observations made at the beginning of this section support this hypothesis. M1 appears as if emerging from up out of a cloud layer (recall the slight tail in Figure 9a and gradual brightening measured in Figure 10). It then moves along the horizon over an appreciable distance (Figure 9) prior to the flash. Although this is the only hypothesis that is consistent with the data, it is at the same time seemingly impossible. If M1 is at the physical horizon then it is a most extraordinary object. Its distance, about 2700 km from the shuttle, implies that from the point where it appears in the video to the point where it seems to stop prior to the flash, its velocity is about 25.8 kmlsec. Then, after the flash it changes direction and accelerates within seconds to a speed of 400 kmlsec!

5. Other Objects

With reference to Figure 16, if an object is within or behind the atmosphere, the image brightness T is proportional to the sum of the object radiance F plus the atmospheric path radiance G (Case 1). If the object is between the atmosphere and the sensor and is smaller than the resolution limit of the sensor, then $F \leq T \leq F + G$ (Case 2). If the object is between the atmosphere and the sensor and is larger than the resolution limit of the sensor, the sensed brightness $T = F$ and the object occludes the background (Case 3).

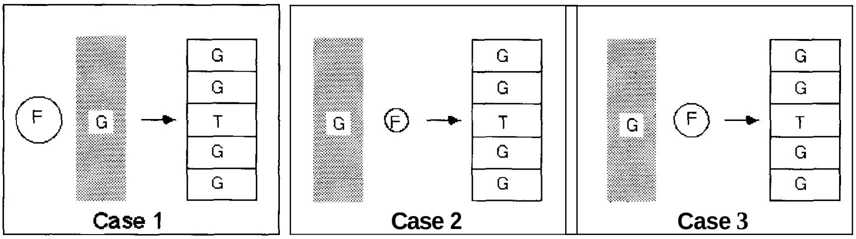
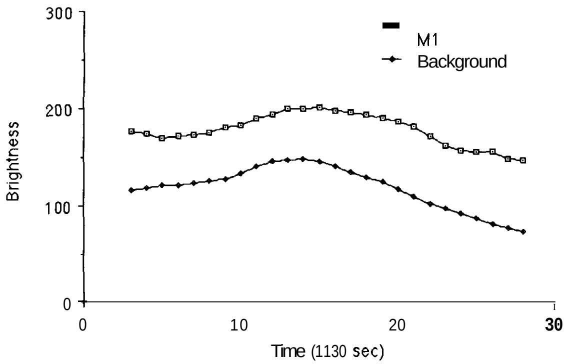
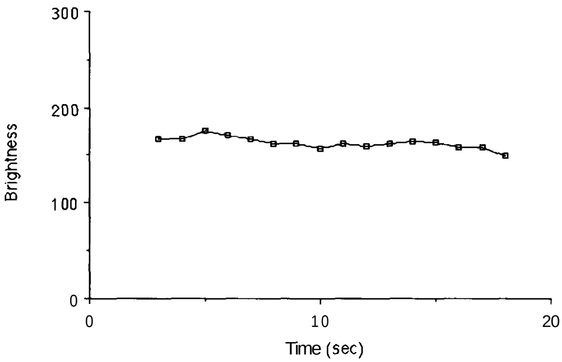


Fig. 16. Object/background models.

The video seems to show two groups of correlated objects. At the left, M1 and MO are one group of objects which appear to change direction at the time of the flash. The other group consisting of M4-M7 appear to change direction about 1.5 seconds later. Figure 17a plots M1's brightness after the flash when it changes direction and briefly passes across the airglow. M1 must be either



(17a)

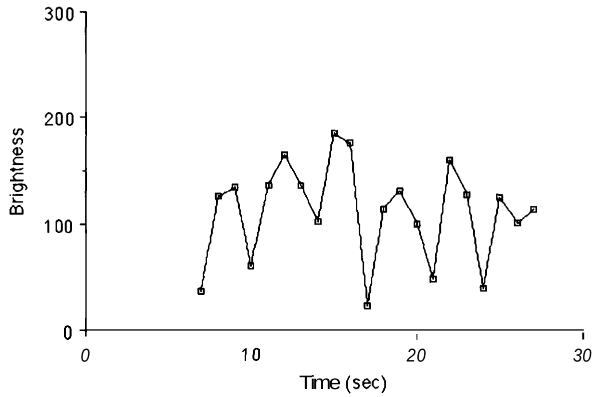


(17b)

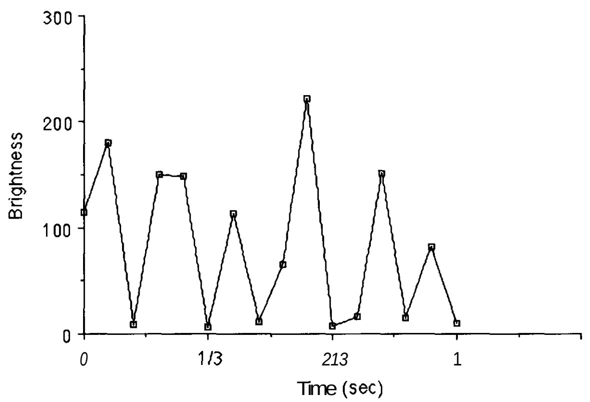
Fig. 17. Objects M1 and M4 moving across airglow.

Case 1 or 2 since it increases in brightness as it passes across the airglow. M4, an object in the second group, appears somewhat brighter and larger in angular extent than M1. Unlike M1, M4's brightness is relatively constant as it passes across the airglow as indicated in Figure 17b. Thus it must be Case 3, either larger than M1 or closer to the shuttle. As noted earlier, M4 appears to change direction 1.5 seconds after M1. Assuming the objects are ice particles that are roughly the same size, the above brightness measurements suggest that the objects in the first group are farther away, yet they appear to be affected by the thruster gases and change direction first. This apparent inconsistency further decreases the likelihood that the thruster firing/ice particle hypothesis is correct.

While objects such as M1 and M4 exhibit a relatively constant brightness



(18a)



(18b)

Fig. 18. Brightness fluctuations of M6 and ice crystal.

over time, others do not. For example, M6 pulsates at a rate of about 5/16 cycles per second (Figure 18a). We contrast this with the brightness fluctuations of ice particles reflecting sunlight. Figure 18b shows the brightness fluctuation of an ice particle released in the separation of the Apollo Command/Service Module from the LEM/Saturn V third stage[4]. The ice scintillates at a much faster rate — about 7 cycles/second compared to less than 0.5 cycles/second for M6. Typically there is a range of rotational rates with larger ice particles rotating more slowly (longer fluctuations) than smaller ice particles. All of the objects in the shuttle video appear to be about the same size, yet some scintillate and others do not.

The above observations suggest that we may be viewing a variety of objects — some closer to the shuttle than others, some pulsating, and others relatively constant in brightness. Perhaps the strongest indication that, at least, some of these objects are far from the shuttle and moving in independent trajectories is evident in the following set of measurements. A time average of 126 frames (1/3 second apart) from the right portion of the video frame is shown in Figure 19. The three right-most traces are from M7, M6, and M4. M5 is too faint to be visible in this rendition. M3 (Polaris) is the straight line near the center of the picture. One can clearly see that the paths of M4, M6, and M7 are not straight lines but circular arcs. Prior to the alleged thruster firing, any debris near the shuttle that had been previously accelerated would appear to move in a straight line. On the other hand, an object moving in a different orbit far from the shuttle would follow a circular path. By measuring the arc length A and chord C distances along an arc, the angle θ subtended by the arc can be found by solving the following transcendental equation:

$$2\left(\frac{A}{C}\right)\sin\left(\frac{\theta}{2}\right) = \theta$$

For M7, we obtained arc and chord distances of 52.01 and 51.87 pixels from

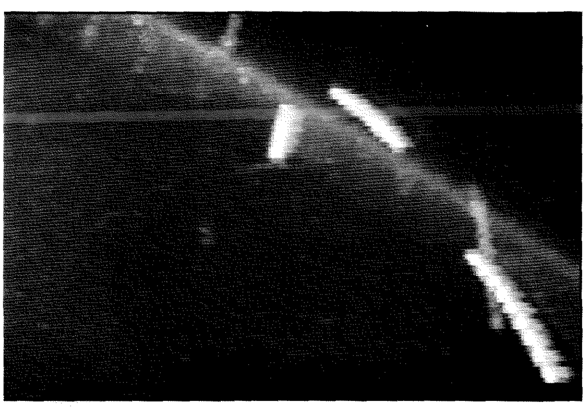


Fig. 19. Time average ot objects M3, M4, M6, and M7.

averaging several sets of measurements. The angle was computed numerically and found to be 12.4 degrees. M7 cannot be orbiting the earth since the angular velocity 12.4 degrees/42 seconds = 0.29 degreeslsecond is too fast. We conclude that M7, M6, and M4 are far from the shuttle, moving around the earth, but not in orbit. If M7 is at about the same altitude as the shuttle, its estimated velocity is on the order of 35 km/sec. This is about the same speed M1 moves from point A to B along the horizon if we assume that it is at the physical horizon.

At the end of the event, the shuttle's camera pans down to reveal a number of objects moving below the shuttle. Figure 20 is an enhancement of the largest object obtained by time averaging several registered video frames to reduce noise. The object appears to have a definite structure consisting of three lobes arranged in a triangular pattern.

6. Summary

Our analysis of the STS-48 video shows that the "ice particle/attitude thruster firing" hypothesis is not consistent with the observed behavior of the objects in question. The firing of an attitude control thruster might have altered the trajectories of particles close to the shuttle but would also have altered the apparent motion of the background (i.e., the earth's limb and the stars). Yet, no such change was measured in the video data.

We found that one of the objects (MI) emerges from point just below the horizon line. Rather than suddenly appearing, its brightness increases gradually over ~ 1 second interval. It moves in a path parallel to and just below the horizon line as its brightness remains relatively constant. The object then slows down, changes direction, and accelerates just after a flash is observed. It moves at a constant velocity across the earth's limb, atmosphere, and airglow layer decreasing in brightness by at least a factor of 1/2 over a 7 second interval. The decrease in brightness implies that the distance from observer increases by at least factor of $\sqrt{2}$ over the same interval. We hypothesize that MI

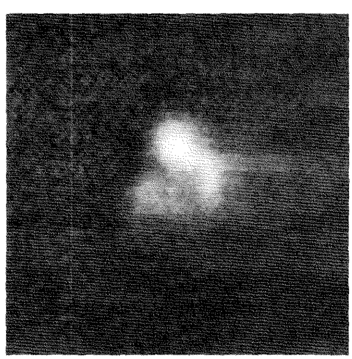


Fig. 20. Triangular-shaped object moving below shuttle.

emerges from up out of a cloud layer at or near the physical horizon, moves parallel to the horizon, changes direction, and rapidly moves away from the observer. If this hypothesis is correct then M1 must be very luminous to be detectable at such a great distance. Assuming a distance of 2700 km from the shuttle, the apparent magnitude of M1 (between 2 and 3) implies an intrinsic luminosity of between 2 x 10' and 5 x 10' watts.

Time exposures of three other objects M4, M6, and M7 suggest that, on the basis of the curvature of their arcs, they are far from the shuttle, moving around the earth, but not in earth orbit. If M7 is at about the same altitude as the shuttle, its estimated velocity is on the order of 35 km/sec. This is about the same speed computed for M1 as it moves along the horizon assuming that it actually is at the physical horizon.

We believe that the measurements and analyses contained in this paper establish beyond a reasonable doubt that the objects captured in this video are not orbiter-generated debris (e.g., ice particles) disturbed by a thruster firing. However, it is beyond the scope of this paper to speculate on what they might be. It can only be said that they are not meteorites flashing in the atmosphere, as it has been claimed for flashes seen from the shuttles, because the trajectories, velocities, and sudden changes in direction of certain objects studied in this paper are not compatible with this hypothesis.

An attempt should be made in future missions to detect and record similar events. In particular when not otherwise in use, the fore and aft cameras in the shuttle's payload bay should be monitored so that they can be positioned to allow stereo imagery of similar phenomena to be acquired and analyzed.

Acknowledgments

I would like to thank Dan Ratsch for recording this extraordinary video and Richard Hoagland for sharing it with me.

Journal of Scientific Exploration, Vol. 9, No. 1, pp. 65–70, 1995 0892-3310/95

Report of Referee On "Digital Analysis Of Anomalous Space Objects"

IRWIN WIEDER

459 Panchita Way, Los Altos, CA 94022

Introduction

Carlotto's analysis of a video taken during shuttle mission STS-48 is an attempt to support the notion that this video depicts an extraordinary event (Carlotto, 1994). However, he does not fully explore the possibility that some or all of his measurements may have prosaic explanations and considers mainly the aspects that appear at first sight to be unusual. The paper purports to show that the objects in the video are far away from the shuttle and as a result their observed motions imply extraordinary velocities. To this end, he has made a number of questionable assumptions and arguments which result in serious doubt about his conclusions.

General Remarks

To put this video into perspective, the event occurs just as the shuttle is corning out of the darkness and into the sunlight. That is just the time when any nearby objects traveling along with the shuttle become illuminated and visible. The objects which were studied evidently did not appear until the sun was in position to illuminate them. There is no mention in Carlotto's analysis of any object appearing while the shuttle was still in total darkness. This fact alone puts doubt on the possibility that the objects were far away from the shuttle. **A** second point to be considered is that ice crystals formed from material released by shuttles and drifting along in orbit with the craft are commonly observed as the shuttle proceeds out of the darkness and into sunlight. The appearance of these ice crystals is very much like that of the objects studied in Carlotto's paper. **A** third significant point is the firing of a vernier thruster capable of disturbing ice crystals nearby just after the shuttle passes into sunlight (undoubtedly a more rare event).

It is this writer's position that because of these three factors there is a high probability that the explanation by the NASA scientists is the correct one. This position is strengthened by examination of some of Carlotto's arguments in the following sections.

Arguments Concerning Thruster Firing

In the paper the point is made that because there is no apparent change of the star trail direction after the flash, it cannot be from an attitude changing thruster — this despite the fact that it has been found from a telemetry playback (Oberg,1994) that there was indeed a firing of a vernier thruster for one second at the time of the flash. Rather than pursuing the precise moment of the firing of the thruster and comparing it with the time the flash was observed, Carlotto apparently decided to try to prove that the event was not correlated with a thruster-firing by analyzing data directly from the video. He attempted to show that there was no evidence of a thruster-firing because he did not detect any change in the star trails as a result.

The question arises as to why Carlotto did not detect any angular displacement. Using his own numbers for a one second vernier thruster burn, the expected angular change is between 0.0175 and 0.0363 deg per second following the bum. This is to be compared with the resolution of the system which for one pixel is 0.065 degrees. He then calculated that after 10 seconds the effect would accumulate linearly to an observable shift. However, one would not necessarily expect the orbiter to continue to rotate at a linear rate, since there are torques (Hughes, 1986) which tend to modify the angular rotation rate and which Carlotto did not take into account. Indeed it is the action of the sum of these torques on the attitude of the shuttle which create the need for vernier thruster firings. This may be a small effect but it tends to reduce the already marginal amount of expected accumulated rotation from a vernier thruster firing.

Even if the effect of non-linear accumulation of angular rotation could be neglected, there are other more serious problems. Depending on the angle, theta, between the axis of thruster-induced rotation and the direction the camera was pointing, an additional sin theta factor needs to be included. For a small enough angle theta this factor could reduce the expected shift from the induced accumulated rotation to an undetectable level. Carlotto does not consider this factor.

Most importantly, he apparently failed to realize that for objects at a distance very large compared with camera dimensions the entire field would rotate or shift together during a (small) camera motion. Thus one would not expect the star trails to change with respect to the horizon. It appears to this writer that the only way to detect this kind of motion (if it were large enough to detect at all) would be with respect to the frame edge. Carlotto did not report that kind of measurement.

As for the objects that were analyzed in the paper, if they were near the shuttle one might expect to see some very small shift of their path after the burn, but it is at just this moment that these objects make major changes in their trajectories, evidently from the thruster firing, so that a small angular change would not be possible to observe. Nearby objects far enough away to be out of the range of disturbance by the thruster would also be far enough away to be included in the argument made above on the star trails and the horizon.

Arguments Concerning Ice Crystals

One argument used in the paper was that the period of variation of the light from some of the objects was much different from a similar variation seen in ice particles on a particular different mission (Carlotto, Fig 18). Now the fluctuation of the light scattered from ice crystals is a function of the rate of rotation of these particles. This angular rate is in turn a function of the particle size and shape and the angular momentum imparted to these ice crystals during their formation. Thus, one would expect a wide range of frequencies of variation of scattered light amplitude, certainly from one launch to the next and even within one mission. Carlotto recognized that larger particles may rotate slower than small ones and couples that with the observation that "all the objects in the shuttle video appear to be about the same size, yet some scintillate and others do not" - this in order to cast doubt on the ice crystal theory. However, even if one could judge the size of the objects in the video, this reasoning neglects the factors of object shape and angular momentum which can vary widely from particle to particle. The observation that the period of oscillation of the light observed from these objects is different from that of ice particles on a different mission and that some of the objects scintillate while others do not would be expected and cannot be used to eliminate ice particles.

Arguments Concerning the Distance of the Object M1.

An argument used in the paper against close particles has to do with the sudden appearance of object M1. It is contended that the object is "down track from the shuttle and thus cannot be emerging from its shadow" (Carlotto, Section 4). There is no way to verify this statement without more detail being presented including the exact position of the camera on the shuttle as well as shuttle orientation with respect to the sun. In fact, it is very easy to envisage a geometry whereby there is a shadow area generated in the vicinity of the event by one of the shuttle's wings or a payload bay door, or even the shuttle body itself if the major axis of the shuttle is not in line with the direction to the sun. This would enable the simple explanation that M1 is a small particle relatively near to the shuttle and emerging from a shadow after the main vehicle has already entered the sunlight. This could also explain the 50 second delay between sunrise and the appearance of M1. An examination of Fig.6 in the paper appears to be consistent with this explanation. There is an irregularly shaped area within which there are apparently no illuminated or luminous unknown objects during the entire event. Object M1 starts to become visible at a position corresponding to about 11 o'clock on the edge of the irregularly shaped area, just as it would if it were moving out of the shadow defined by this area.

Another argument in the paper is that the object M1 appears to increase in brightness over a one second interval just after it appears,"instead of abruptly as one would expect of an ice particle near the shuttle passing from shadow into sunlight," and the claim is made that this observation obviates the possibility that the object is an ice particle nearby. Actually, because of the angular diameter of the sun (approximately one half of a degree) and the particle motion, one can account for a gradual increase in illumination in the one second range if a small object is coming out of a shadow near the shuttle.

If one assumes that the objects are indeed small debris particles nearby to the vehicle then the direction changes for all objects that change course is consistent with collisions of debris particles with bum particles or molecules. These particles or molecules would evidently be coming from the left and at a slight angle with the bottom of the frame. Note that the variety of angles of the debris particles' new trajectories could be a result of their different masses and momenta. The expected trajectories of particles affected by the burn stream would be difficult to calculate because of the unknown parameters (mass and velocity of debris particles, mass and velocity of bum particles). Also, such a calculation may need to take into account other possible effects during the temporary rise in pressure (Pearson, 1990) in the vicinity of the jet releasing the bum gas. As an example, photophoresis has been known to produce strange motions of small particles at low pressure (Ehrenhaft et al, 1951). This effect has been analyzed and is now reasonably well understood (Preining, 1966).

Conclusion

1 do not agree with the author that he has shown "beyond a reasonable doubt" that the objects are not nearby debris. On the contrary, I believe that the evidence suggests that these objects are most certainly small pieces of debris or ice crystals very near the shuttle which have been disturbed by a thruster firing.

Despite my disagreement with the author's conclusion I would like to commend his effort in taking a scientific approach towards understanding an unusual phenomenon. If we are to make any progress towards understanding the UFO phenomenon we will need to have a large and continuing effort in that direction.

References

Carlotto M. J. (1995). ***Journal of Scientific Exploration,*** previous paper
Ehrenhaft F. and Reeger E. (1951). ***Comptes Rendu,*** P.385, 23 July.

Hughes P. C. (1986). ***Spacecraft Attitude Dynamics,*** Chapter *8*. John Wiley and Sons, NY.
Oberg J. (1994). (Private communication).
Pearson D. M. (1990). ***Plume Impingement Modeling.*** *NASA* JSC/DM.
Preining O. (1966). ***Aerosol Science.*** Davies C. *N*. ed. Chapter 5, Academic Press, London.

Carlotto's Response to Wieder

MARK J. CARLOTTO

Wieder begins with several general remarks in order to establish a context for the event. He then goes on to make a number of specific comments concerning the results of my paper. Let me first address his major criticisms. I will then conclude with some reactions to his general comments.

I state in the paper that a lack of detectable change in star motion implies that the flash was not due to a thruster firing. Wieder suggests several reasons why this may not be so: the effect of torques on the orbiter, the direction of the burn, and a possible error in the method used to measure displacements in the field of view. My estimate of the angular displacement of the shuttle was based entirely on a first order analysis that neglected the torques. Wieder does not provide an estimate of the magnitude of these torques so it is not possible to assess their significance relative to the event. I also neglected the "sin theta" factor (theta being the angle between the direction of the burn and the direction of motion of objects in the camera's field of view). If theta is small then there would be little change in the direction of star motion (there would be a slight acceleration but it might be difficult to detect). On the other hand, if theta is small, the position of the horizon would shift by the maximum amount since it is roughly perpendicular to the direction of star motion. Yet no significant horizontal shift in star motion nor vertical shift in the position of the horizon line was detected in the video. Finally, to clarify a point of confusion — Wieder seems to think that the star motion was measured relative to the horizon. All measurements reported in the paper are relative to the upper left corner of the frame not relative to the horizon.

Obviously this debate about a thruster firing is academic. Although James Oberg indicates through private communication with Wieder that a thruster firing did take place, I would invite Oberg to produce documented evidence to this effect. Such evidence would settle this question once and for all.

I note that some objects in the video scintillate while others do not. I agree with Wieder that this is not significant in itself. What is unusual is that M1 does not scintillate at all, neither before nor after the thruster firing. This seems odd because one would expect a plume of gas to alter both the lateral and angular motion of particles and thus change the manner in which they reflect light. But the thruster firing does not seem to alter the brightness characteristics of any of the objects. This implies that the objects are not affected by the gases and must thus be far from the shuttle.

Wieder constructs an alternative scenario to explain the gradual appearance of M1 that assumes that the major axis of the shuttle is not in line with the sun.

This would result in a situation where the camera is in sunlight but portions of space near the shuttle are in shadow. It's not obvious to me how this shadow geometry could produce a circular-shaped shadowed region in the camera's field of view. Only if the sun was in front of the shuttle and the camera was looking backwards could a roughly circular shadow occur within the field of view. But I showed that the shuttle is in fact looking north with the sun about 90 degrees to the right so the geometry suggested by Wieder is impossible. There is yet another problem with his explanation: For an extended light source such as the sun, the width of the transition zone of a shadow and hence the period of brightening depends on the distance between the object moving out of shadow and the body producing the shadow. For an ice particle moving out from just behind the shuttle, one would have to know its distance from the part of the shuttle casting the shadow as well as its velocity to state the period of brightening is in the one second range. No analysis is provided and so this explanation is speculation.

The object that I call M1, the flash (purportedly due to a thruster firing), and the change in the motion of M1 after the thruster firing are at the center of the debate about this video. I spend a great deal of time in the paper discussing the motion and radiometric properties of M1 as well as several other unusual objects seen in the video. Wieder ignores these objects. In particular, if M4, M6, and M7 are near the shuttle how can they be moving in curved trajectories? Such motion suggests instead that they are far from the shuttle and traveling at great speeds. Also not mentioned is the triangular-shaped object seen at the end of the video. This object is almost certainly not ice or orbiter-generated debris.

Wieder's general comments concern me most. He states at the outset that the objects appear after only after the shuttle enters daylight, that ice particles are often observed drifting along with the shuttle, and that one of vernier rockets would be capable of disturbing ice particles near the shuttle in a manner similar to that observed in the video[1]. He then states that because of these factors there is a high probability that the explanation by NASA is a correct one. He implies that because the event seems ordinary it is ordinary; in other words any analysis of the data would hold little weight against the strong prior belief that the objects are simply ice crystals.

I believe that one must be a careful observer in order to witness extraordinary events. This means that a balance must be achieved between prior belief and observational evidence. Only in this way can we assess these and other unusual phenomena in a truly objective manner.

---

[1]Jack Kasher has produced five proofs that the objects seen in the video are not ice particles disturbed by a thruster firing. His analysis is based on the interaction of the gas plume emitted by a thruster and it interaction with nearby particles and is presented in detail in a video entitled "A scientific analysis of UFOs appearing on video footage taken by NASA during Discovery Space Shuttle mission STS-48," distributed by AFS/Dialogue, Minneapolis, MN, 1994.