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Examination of Object Trajectories in the STS-48 "UFO" Video

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A frame overlay method previously applied by Carlotto to the STS-48 video frames revealed that some of the unidentified objects followed curved trajectories, indicating that they experienced prolonged periods of acceleration that cannot be attributed to the relatively brief firing of a shuttle thruster rocket acting on nearby debris particles. The same method was reapplied to the video but over considerably longer periods of elapsed video time than those originally covered by Carlotto. It was found that two of the objects changed their courses from initially linear trajectories to highly curved trajectories. This and other details revealed by the longer time span overlays tend to rule out explanations for the path curvature that would be consistent with the shuttle debris interpretation. Rather, the newly-revealed aspects of the objects' trajectories strongly support Carlotto's interpretation: that the path curvatures are evidence that some of the objects are large, self-propelled, and closer to the Earth's horizon than to the space shuttle.

Introduction

In a 1999 paper[i] on objects appearing in a video sequence recorded by the Space Shuttle Discovery on September 15, 1991 during the STS-48 mission, Carlotto showed that several of the objects have trajectories with a small but noticeable curvature. This can be seen in Figure 1, an image copied from that paper. Carlotto constructed this image by combining frames taken from the video at regular time intervals of 1/3 second. This curvature suggests that the objects were accelerating in the absence of any external force and therefore may have been self-propelled. Records obtained from NASA show that none of the space shuttle's thrusters were firing during the time period covered by this composite image and so could not have provided the accelerating force necessary to deflect the objects from linear paths.

Two possible explanations have been suggested for the curved trajectories that do not require any extraordinary conclusions to be drawn:

- The curvature is a distortion of the image caused by the camera itself.
- The curvature is real, but the objects are ice particles accelerated away from the sun by the pressure of ice sublimating into gas from the particles' surfaces heated by exposure to sunlight in the vacuum of space.

Figure 1. "Time exposure" from [1]. The straight-line segment near the center is the North Star.

To evaluate the validity of these explanations, time exposure composite images were constructed with Carlotto's method but using much larger time intervals between captured frames. Composites using larger time intervals provide a view of the objects' behavior over wider time spans and reveal some remarkable aspects of these objects' behavior not evident over the shorter time spans previously investigated by Carlotto. They also show possible evidence of the shuttle thruster firing that has been suggested as the cause of the objects' motions by proponents of the hypothesis that the objects are shuttle debris. Both of these subjects are discussed here.

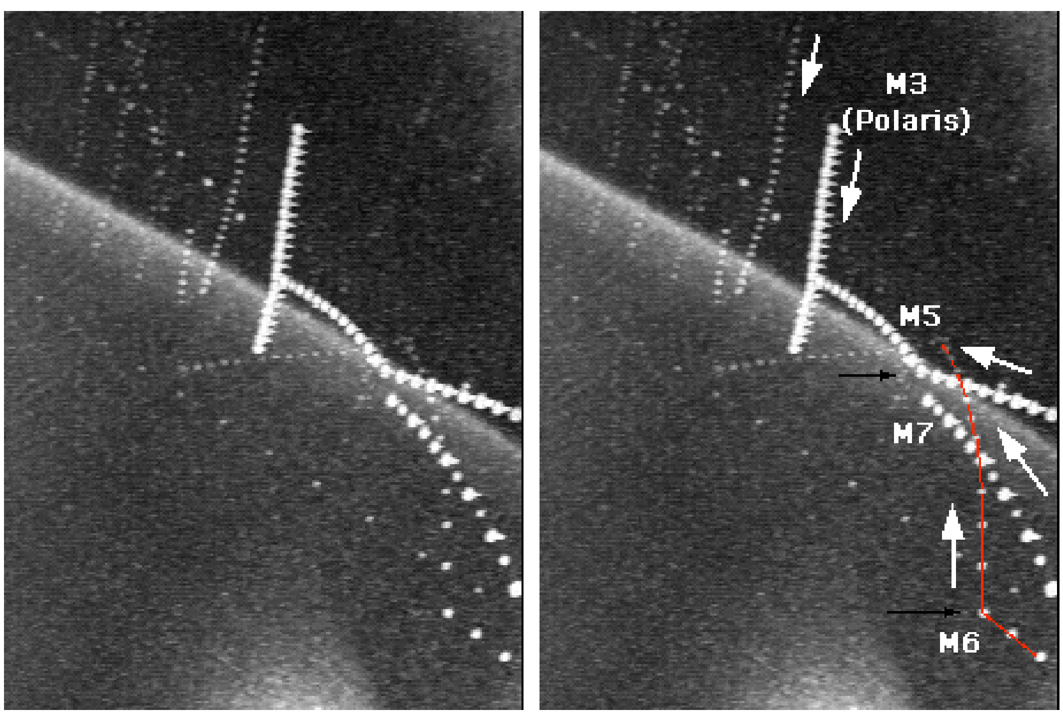

Figure 2. Time exposure of the right-hand section of the STS-48 video. Objects are labeled as in Reference i in right-hand image. White arrows indicate directions of motion. Black arrows indicate positions of objects M5 and M6 at the time of the light flash. Path of M6 is delineated in red.

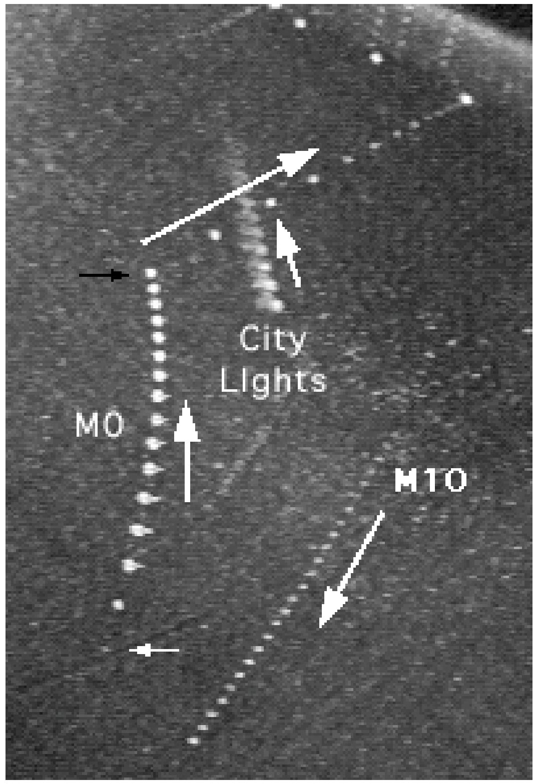

Figure 3. Time exposure showing the curvature in Object M0's trajectory. The small white arrow indicates the position at which the object first appears. The black arrow shows its position near the moment of the light flash. Large arrows show directions of motion of M0, city lights, and a second object designated M10 that appeared after M0 and moving in the opposite direction. Time interval between overlaid frames is 5 seconds.

A View of Object Trajectories Over Two Minutes

The images shown in Figure 2 used intervals of 5 seconds between video frames rather than Carlotto's 1/3 second. The light flash originating in the upper left of the video occurs about midway through the two-minute period of time represented by this image.

The positions of objects M5 and M6 indicated by the black arrows clearly show that they both responded to the light flash with radical changes in course, but not in a way that would be expected for small debris particles responding to the firing of a shuttle thruster. Object M5 immediately alters its original linear course and can be seen to follow a curved trajectory for more than one minute, until the camera pans down toward the cargo bay. The shuttle's L5D vernier thruster, which has been suggested as the cause of the objects' motion, fired for only 1.2 seconds. If M5 were a debris particle, the curved segment of its path could exist for only 1.2 seconds, well below the time resolution of the time exposure composite of Figure 2.

At the moment of the light flash, Object M6 alters its course from one linear trajectory (from lower right toward the upper left) to a different but still linear course (moving almost straight up in the image). This course change would be consistent with a debris particle responding to a thruster firing, but there is a second course change that is not. The second change in course puts M6 on a trajectory curving to the left, again indicating some force began accelerating the object about 15 seconds after its initial response to the light flash.
The first object to appear in the STS-48 video sequence, designated M0 by Carlotto, also was found to have a strongly curved path as shown in Figure 3. A second object, designated here as M10, follows a nearly linear path with a slight bend near the time of the light flash.

It is the changes from linear to curvilinear motion of Objects M5 and M6 that most strongly suggests that neither "prosaic" explanation for the objects' curved trajectories can be correct, as discussed in more detail below.

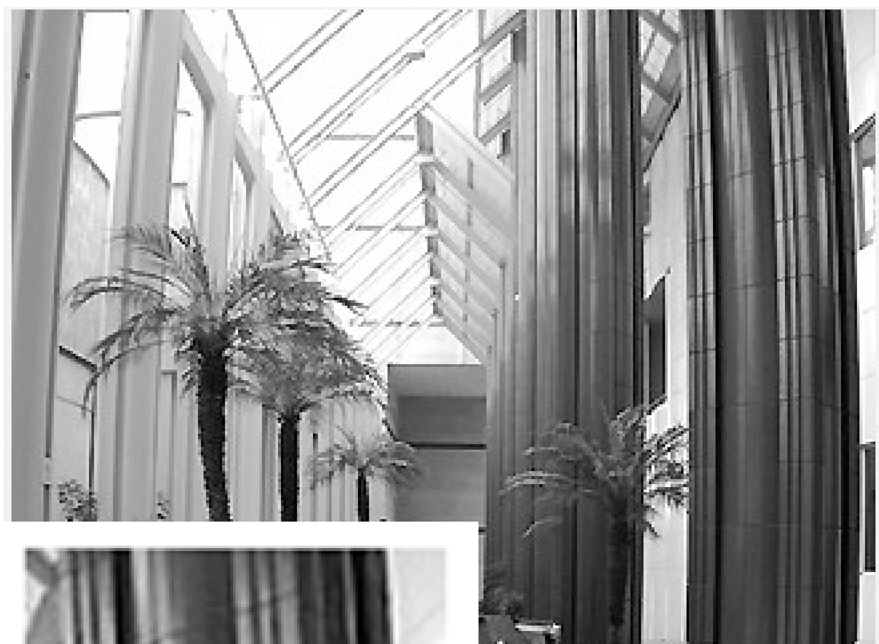

Figure 4. Example of a wide-angle image. Curvature of columns and window frames is "barrel distortion" associated with the wide-angle lens. The inset at lower left demonstrates that the curvature caused by the lens cannot be detected over a small fraction of the image length. Photograph from reference ii.

Curvatures Introduced by Lens Distortion

If "barrel distortion" of the sort associated with wide-angle lenses were responsible for the curved trajectories, then the most highly curved section of Object M6's path should be the section running straight up toward the top of the image, with the convex side of the curve facing to the right. As shown in the wide-angle photograph[ii] of Figure 4, barrel distortion is most pronounced at the outer edges of the image where M6 follows a straight path. It seems very unlikely that the lens used for the STS-48 video should show any noticeable distortion at all.

"Wide-angle" lenses are those having fields of view greater than about 120 degrees on the diagonal, but the camera used for the STS-48 video had a field of view diagonal of only 50 degrees -- a standard field of view for which no noticeable lens distortions should be expected. Even for photographs taken with a wide-angle lens, the curvature introduced is only detectable in linear features running over a large portion of the photograph, unless the lens angle is extremely wide (e.g., “fish-eye” lenses). The curvature in the column of Figure 4 is unnoticeable over the small section shown in inset on the lower left.

A quantitative measure of an arc’s curvature is the radius of a circle as a function of the chord length, *L*, connecting the two end points of the arc and of its maximum height, *H*, above the chord at its center:

$$R = \frac{\frac{1}{4}L^2 + H^2}{2H}$$

The smaller the radius of curvature, the greater the arc's curvature is considered to be. Expressed as fractions of the respective image diagonals, the radius of curvature of the column in Figure 4 is 1.4 times the length of the photograph’s diagonal and the radius of curvature of the path of Object M5 is 0.1 times the diagonal of the STS-48 camera's field of view. The curvature of M5's path in the STS-48 video, taken by a camera with a normal field of view, is thus about 14 times greater than the curvature introduced by barrel distortion in the moderately wide-angle photograph. In other words, if the arc of M5's path were continued to complete a circle, it would fill only 20% of the image's diagonal length. A circle similarly drawn to complete the arc of the column would not fit in the photograph; it would require an area more than 2.8 times larger than the photograph’s diagonal.

Object M0 is very close to M10, whose path shows no sign of curvature. Barrel distortion should affect linear features in proximity to each other about equally. Finally, the convex side of the curvature of M0’s path points in the wrong direction for the curvature to be attributed to barrel distortion. Barrel distortion would cause the convex side of the curve to be on the left because the object is left of the center of the FOV. But the convex side of M0’s path points to the right, as do the paths of M5 and M6 on the right side of the image.

Sublimation As a Propulsive Force

There is nothing substantive to support the lens distortion interpretation of the curvature and conclusive evidence against it. Sublimation of ice from the objects themselves, however, would seem a much more plausible explanation, assuming that the objects are small ice particles.

All of the objects' path curvatures have their convex sides to the right, so whatever propulsive forces were involved were deflecting the objects toward the left. Water ice sublimates (transforms directly from solid to vapor) in a vacuum at a temperature of -73 degrees C. The equilibrium temperature of ice particles exposed to sunlight is largely dependent on the concentration of heat-absorbing impurities in the ice, a factor that is difficult to estimate. Sunlight was coming from the lower right in the camera field of view. If the objects were ice particles, their sunward surfaces would have been heated to a higher temperature than surfaces facing away from the sun. The pressure generated by the ejection of any sublimated water vapor from the particle surfaces would have been greater on the sunward side, resulting in a net force deflecting the objects toward the left as seen in the video. This much is consistent with the sublimation hypothesis.

However, if the objects were ice particles propelled by sublimation, then it seems likely that all of them would have followed curvilinear paths from the moment they entered the camera's field of view because all were exposed to sunlight the entire time. While M0's path is, in fact, initially curved and remains so until it reacts to the light flash, the paths of M5 and M6 are initially linear. Object M5 changes from a linear to a curvilinear path at the exact time of the light flash. It would seem a highly unlikely coincidence that an ice particle, initially colder than the temperature at which sublimation occurs, would be heated to the sublimation temperature exactly at the time the light flash occurred. No indication of curvature can be seen in M6's path until around 30 seconds after it has entered the camera's field of view. Object M6 changes course at the moment of the light flash, but remains on a linear trajectory until just before reaching the horizon -- another seemingly implausible coincidence.

Carlotto hypothesized that M5, M6, and M7 all followed curvilinear trajectories at the horizon because they were moving around the curvature of the Earth. While M0 was not at the horizon, it, too, may have been following the curvature of the Earth. This would explain why all the observed curvatures have their convex sides pointing to the right, which is also the orientation of the Earth's curvature. If M5 and M6 were really near the horizon, they would have been traveling at velocities considerably greater than orbital velocities. Self-propulsion, in addition to the Earth's acceleration, would have been necessary to maintain these trajectories.

Also of possible significance is that the path of Object M0, which initially curves away from the sun, shows a small deflection toward the sun after the light flash event. As shown in Figure 5, the final position of M0 is to the right and below the position it would have had if it were following a linear trajectory. This sunward curvature in M0's path is inconsistent with the sublimation hypothesis.

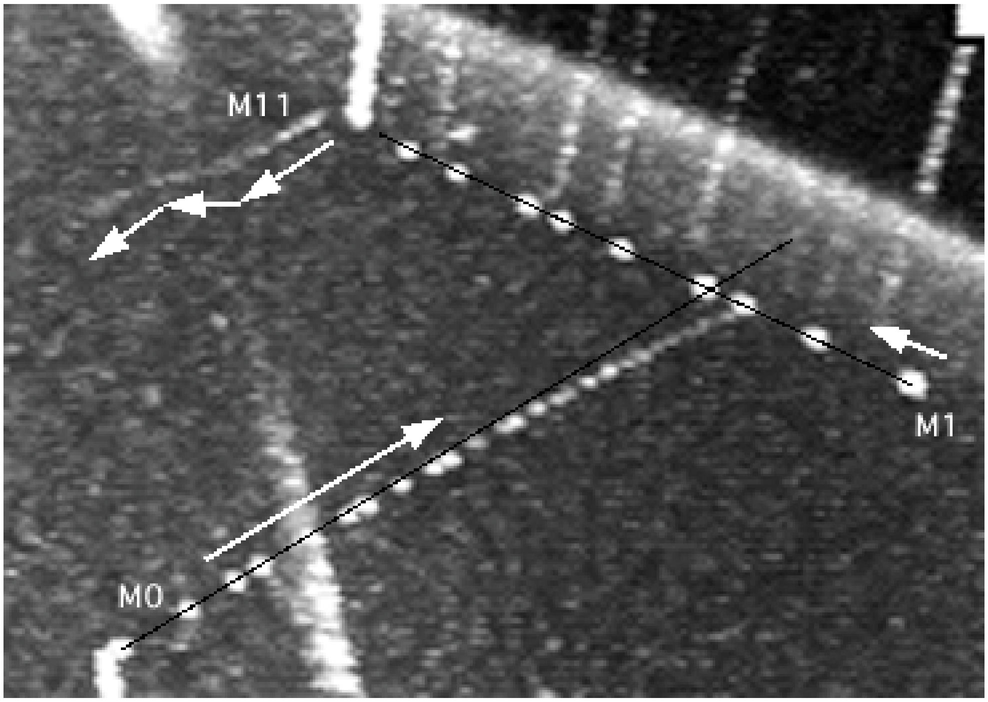

Figure 5. Enlargement of time-exposure overlay showing deflection of Object M0 toward the lower right, the direction of the sun, after the light flash. Object M1 shows no detectable deflection from its linear course prior to the light flash event. The object designated M11 also changes course at the moment of the light flash but then resumes its original heading. Arrows indicate direction of object motion.

The object designated M11 in Figure 5 is one of several objects not previously noted, probably due to its faintness relative to other objects. But the track it leaves on the time-exposure overlay is worth comment. Like the better-known M1, M11 makes its first appearance at the horizon, repeating that remarkable spatial coincidence (note that the track of a bright star ends very close to the point where object appeared). The object veers from its original course at the moment of the light flash. With seeming stubbornness, it resumes its original heading about 30 seconds after the light flash and in opposition to any propulsive force generated by sublimation if it were an ice particle.

A Linearly Accelerating Object

About a minute after the light flash and associated changes in object trajectories, the camera begins panning down to the cargo bay. There are two more instances of objects moving at a high enough angular speed to leave streaks on the image. What is of interest is that one of them is increasing in angular speed as it moves from the bottom to the top of the field of view. A time-exposure composite of this object is shown in Figure 6. Because the camera was moving, the frames used were registered to the position of one of several objects that appeared to be stationary relative to each other and so very probably stationary relative to the shuttle. As can be seen in the inset at the lower right, the object is moving faster just before it exits the field of view than when it entered. The measured increase in angular velocity is 25% to 30%.

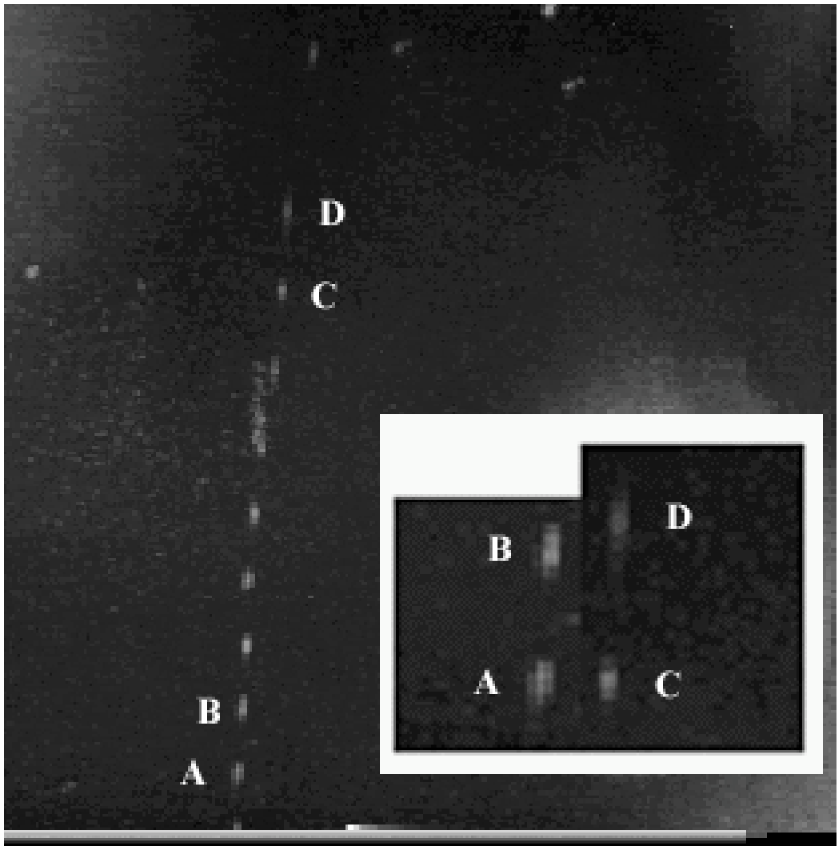

Figure 6. Time exposure overlay of an object moving at a high angular rate 1 minute after the light flash event. The object's position is shown at half-second intervals except at the top, which is near its final position before it exited the field of view due to its own motion and the panning of the camera. The elapsed time between that position and its previous position at C is 0.87 seconds.

There are two possible explanations for the apparent increase in speed: either the object is approaching the shuttle or it is accelerating through space. The decrease in brightness with time seems to rule out the possibility that the object is approaching the shuttle. The maximum brightness measured for the object decreases from 164 DN where it first appears in the FOV to 100 DN near the point where it exits the FOV. The background brightness of outer space at this point in the video is about 52. Taking 52 DN as the baseline value for "black," in the image, the object's maximum brightness relative to the background decreases from 112 to 48. That is more than a 50% decrease in brightness. The increased velocity of the object could itself account for some of the decrease in brightness, since the total amount of illumination of a pixel is proportional to how much time it takes for a light source to move across it. But the

~30% increase in speed would account for only about a 25% decrease in brightness, only half of the observed decrease.

Therefore, the brightness decrease seems to be due primarily to the object moving away from the shuttle. If so, then its linear acceleration is greater than the apparent increase in its angular velocity would suggest. An object moving at a constant linear speed away from the camera would appear to slow down rather than accelerate, and a linear acceleration would be necessary just to maintain a constant angular speed relative to the camera.

This object appears approximately one minute after the firing of the shuttle's L5D thrusters and one minute before the next thruster firing. As was the case for objects following curved trajectories, there is no apparent external source of propulsion to account for the increase in speed, suggesting that it, too, may have been self-propelled.

Star Tracks and the Shuttle Thruster Firing

In Figure 2 it can be seen that there are fairly distinct bends in the tracks made by stars, including Polaris. These bend points occur close to the point in time at which the light flash event occurred. Of course, a flash of light cannot affect the paths of stars, so the apparent change in the direction of the stars' motion can only be due to a movement of the camera or the shuttle itself. It is the author's opinion that this course change is due to the firing of the space shuttle's L5D vernier thruster. This may seem at first glance to be good evidence that the flash of light was also caused by the thruster, implying that all of the objects that reacted to the light flash are in fact merely small debris particles, despite all of the evidence to the contrary.

But a closer examination reveals that, if anything, the star tracks indicate the light flash may have occurred at a time between 5 and 10 seconds after the thruster firing. As can be seen in the enlargement of the time exposure overlay of Figure 7, the position at the time of the light flash of each star shown does not seem to fall at the intersection of the track it followed prior to the thruster firing and the track it followed afterward. Instead, it appears that the position each star occupied 5 seconds before the light flash is closer to the point in time at which the direction of motion changed.

In a previous article[iii] by the author it was proposed that the best estimate for the time of the light flash was 6.5 to 8.5 seconds after the thruster firing. That estimate was derived from data on the shuttle's position and the transit of the star Polaris of the Earth atmosphere's airglow layer and was completely independent of what these star tracks appear to show.

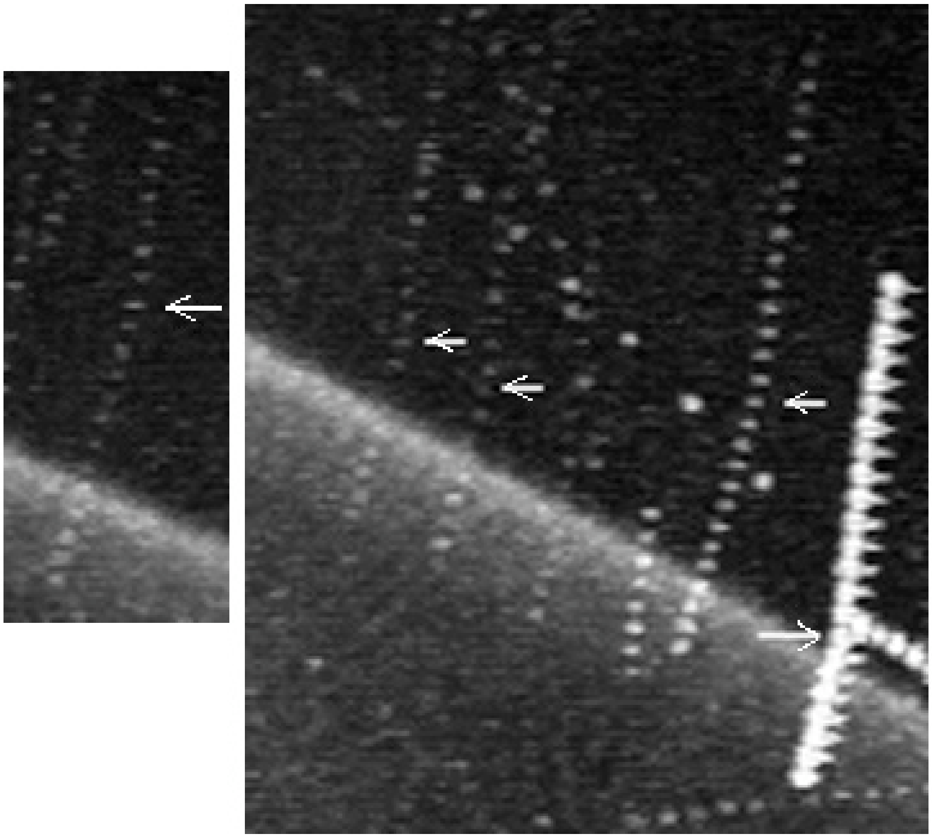

Figure 7. An enlargement of a time exposure overlay using frames at 5-second intervals. Arrows indicate positions of five stars at the time of the light flash event. The positions of the stars at the point just above and 5 seconds prior to the light flash appear to fall closest to the intersection of the tracks before and after the thruster firing.

However, there is probably too much scatter in the data to establish any statistical basis for concluding that the time-exposure images support a time difference of 5 to 10 seconds between the rocket firing and the light flash. The positions of one of the stars shown in Figure 7 (Zeta Octantis) were programmatically reduced to points. The program identified the star image for each time interval as the set of contiguous pixels above a certain threshold brightness value. It then computed the point position of the star as the average of the pixel positions weighted by their brightness above the local background brightness.

As shown in the left-hand part of Figure 8, the result for the time exposure seem to support the subjective impression that the light flash occurred 5 to 8 seconds after the change in the star's course, which would rule out any causal relationship between the two events. But when more points are added by the same procedure applied to two other time-exposure images, it is less clear at what position the change in the star's course occurred as shown by the right-hand part of Figure 8.

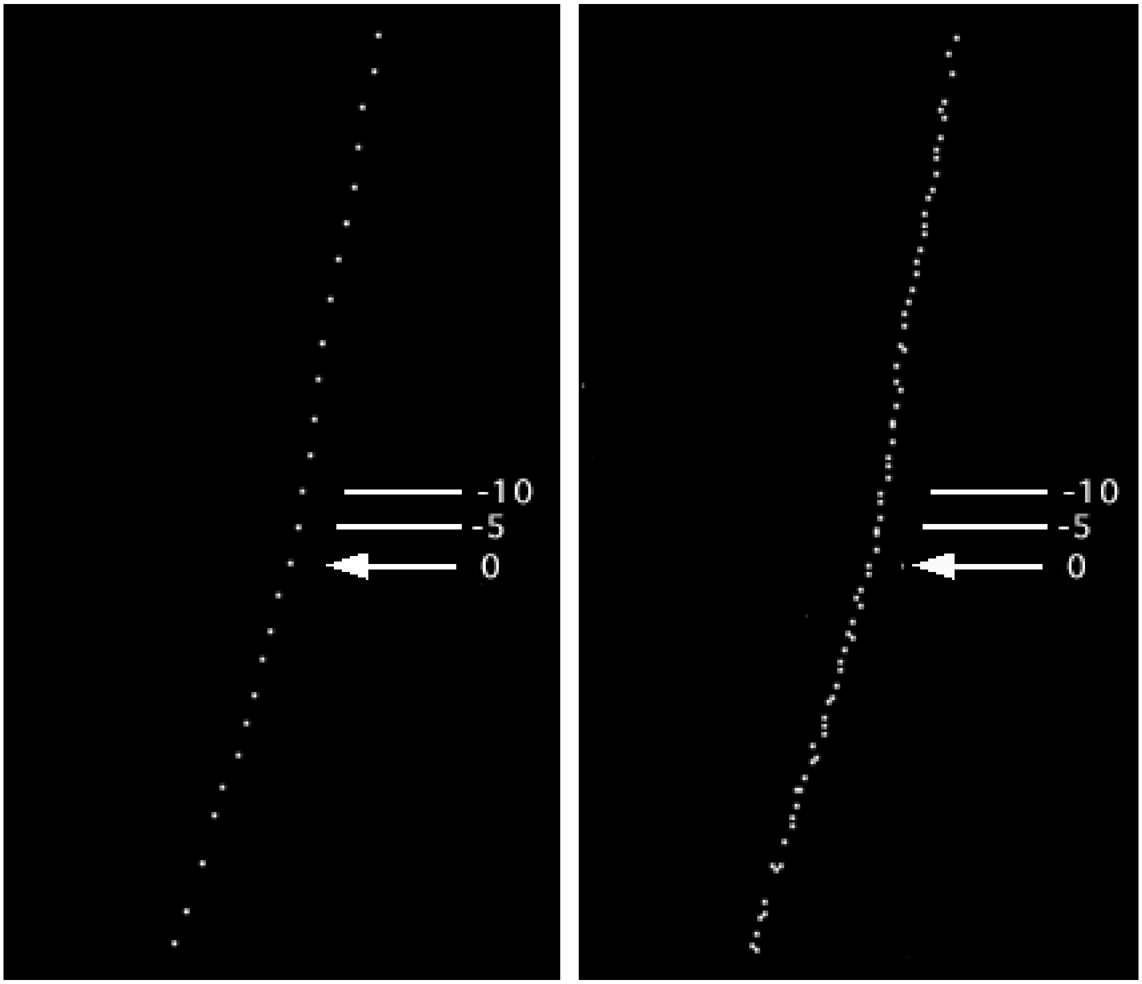

Figure 8. Left: Track of the star Zeta Octantis at 5-second intervals with image s of the star reduced to a point. The arrow labeled "0" marks the star's position at the time of the light flash. Other lines indicate position of the star 5 and 10 seconds prior to the light flash. Right: The track of the same star but with additional points offset by 2 and 4 seconds from the light flash added.

Perhaps a better point-identification algorithm or a larger sample of video frames would produce statistically significant results, but this seems doubtful. It appears that the video resolution is simply insufficient to determine the time of the course change within a span of a few seconds. While these results do not positively support the previous estimate of the time elapsed between the rocket firing and the light flash, they also do not contradict it.

Conclusion

All of the objects in the STS-48 video discussed here were near or below the resolution of the camera and they do not differ in appearance from small debris particles near the shuttle. This lack of resolution has been cited as one of the reasons to assume that the objects are, in fact, shuttle debris. But it is obvious that other objects in the video that also "look like" debris particles in a single video frame are actually stars. It is the uniform linear motion of the stars when the video is run that clearly distinguishes the stars from any nearby shuttle debris. Similarly, it is the curvilinear motions of the unidentified objects in the video and the change of some of them from linear to curvilinear trajectories (and back again to linear in the case of M11) that most strongly distinguishes them from drifting shuttle debris. These trajectories are inconsistent with those of debris propelled either by a shuttle thruster or by sublimation. They are, however, consistent with the flight paths of large self-propelled objects moving around the curvature of the Earth.

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[i] Mark Carlotto, "Digital Video Analysis of Anomalous Space Objects," *Journal of Scientific Exploration*, Vol. 9, No. 1, pp 45-63, 1995

[ii] From PCWorld.Com (URL: http://www.pcworld.com/howto/article/0,aid,80884,00.asp)

[iii] Lan Fleming, " A New Look at the Evidence Supporting a Prosaic Explanation of the STS-48 "UFO" Video" URL: http://www.newfrontiersinscience.com/