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A Scientific Analysis of Four Photographs of a Flying Disk Near Lac Chauvet (France)

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Abstract–A series of four photographs of a disk-shaped object apparently flying in the sky was physically analyzed. Certain details **led** us to develop a mathematical model of the supposed trajectory. The model was validated by measurements on the photographs, which demonstrated that the disk was distant from the camera, flying along a straight and horizontal trajectory, and was not a fabrication.

Introduction

Many photographs of alleged UFOs exist, but even the most convinced ufologists say that none of these provide absolute evidence for the existence of these objects.

Indeed, even if a shot has not been faked and thus represents an object actually photographed, this object may well not be a UFO but a model placed in the landscape. Sometimes, the photographic image may be totally useless for gathering information like, for instance, an overexposed image of a large and bright point observed at night without any reference to the landscape. Such an image may be obtained from anything: the moon, a street lamp, a headlight, etc. The object produces a zig-zag pattern on the photograph, often because of the movements of the photographer who generally handholds his camera and uses long exposure times, and not from the movement of the object itself.

There are some well known UFO photographs, the authenticity of which has been disproved after serious investigations. First, we discuss the famous McMinnville photographs (taken in Oregon in 1950), which were first studied by astronomer William K. Hartmann in the *Condon* ***Report*** [1] [2]. From a microdensitometric analysis of the negatives, Hartmann drew the conclusion that:

"This is one of the few UFO reports in which all factors investigated, geometric, psychological, and physical appear to be consistent with the assertion that an extraordinary flying object, silvery, metallic, disk-shaped, tens of meters in diameter, and evidently artificial, flew within sight of two witnesses."

However, in 1977 engineer Claude Poher, who was the first GEPAN Director, studied these photographs. A geometric analysis of the apparent position of the object with respect to the foreground electrical wires on the two consecutive images convinced Poher that it was, in fact, a small model hung from one of these wires [3].

Second, we discuss the San Jose de Valderas photographs (taken in Spain in 1967) and related to the Ummo case. For these images, there is no doubt that it was a small model hung with a very thin wire. There are two sets of images, allegedly taken with two different cameras (of sizes 24 × 36 and 6 × 6) by two photographers not known to each other and who supposedly took the photographs just when the object appeared. But the analysis of the foreground in the two sets shows in fact that they were taken from almost the same place, the two cameras being side by side, fixed to tripods at 1.15 meters from ground level, probably by the same photographer! Such a "spontaneity" strongly suggests an organized forgery. Moreover, the photometric study of the negatives by Poher proved that the object was translucent [4].

Third is the photograph of a Peugeot car hub cap thrown up in a Corsican pine wood by a small group apparently who wanted to get some money by publishing a poster (obviously a less sophisticated forgery.) A member of this group admitted the hoax later [5]. About sixty attempts (two rolls of 35 mm color film) were required to obtain a correct image of the "saucer." It was published in the French journal Ouranos, and recovered some years later by a technician of the Observatoire de Haute-Provence, who claimed in the presence of Charles Fehrenbach (at that time Director of this observatory) to have taken this photograph himself at the observatory. There was no worse method to convince Fehrenbach of the UFO's existence; the vegetation at the observatory consists of little stunted oaks!

Finally, I will mention my own experience, which was a lesson for me. In 1970, Charles Bowen, Director of the Flying Saucer Review at that time, asked me to assess two photographs taken by night at Warminster, England on black and white 35 mm film. They showed a dimly luminous UFO seen by its side slightly above the horizon, with a row of street lamps in the background [6]. Analysis of the film convinced me that it had not been faked and that this was actually the photographic image of a real object taken through the camera lens. I should not have continued but, since Bowen had sworn to me that the photographers were honest and had seen the UFO, I did not question this and tried to explain some discrepancies between what the photographs showed and what the photographers said [7]. Indeed, it was a trap produced by English "rationalists" who aimed to discredit ufologists. In reality, the UFO was a model slightly lighted and the image of which was superimposed on the landscape by means of a two-way mirror placed in front of the camera. The perpetrators had a good laugh over my "credulity," and made a great to-do about the case thinking that they had demonstrated the deception of UFO photographs. Actually, they had only shown their intellectual dishonesty by deceiving Bowen's trust.

One could deduce from these examples that a UFO photograph, even if not faked, has a persuasive value only if one is confident in the witness's intellectual honesty. This means that no photograph is intrinsically convincing. However, such a judgment is too harsh. First, there do exist photographs which we know were not faked, such as those taken by the military. Unfortunately, few photographs of this kind have been made public, even if some photographs or film (e.g., during rocket launches) have been reported.

However, there also exist photographs taken by amateurs, for which intrinsic analysis is sufficient to prove their authenticity without having to believe the witness's testimony. I think the Lac Chauvet French photographs are a good example of such evidence.

The Lac Chauvet Photographs

Like many other early ufologists, I discovered the Lac Chauvet UFO photographs in Aimé Michel's first book, *"Lueurs Sur les Soucoupes Volantes"* (published by Mame), which I bought in August 1954 when it was published [8].[1] These photographs had been taken two years before by an engineer named Andre Frégnale. Two of them were included in the book with a short comment, in fact incorrect, relative to the order of the shots and to the direction of the object's movement. These photographs displayed a disk viewed obliquely like an ellipse flattening with distance, in a very clear summer sky. The horizon was not visible on these images, but it was obviously very near to the lower limit of the photographed field. Stratified cumulus in the background, such as one can observe near the horizon, appeared at the bottom of one image; a little grassy hillock was visible in the foreground of another one. These details permitted a first evaluation of the object's angular height, provided the focal distance of the lens was known. The lower part of the UFO was dark, and no detail was visible on the published images. The upper right edge of the ellipse looked bright, as if sunlight had been reflected by the object.

These photographs were interesting to me because of their clarity and of the qualifications of the witness, who had very precisely observed the object and did not believe in flying saucers. At the end of his observation, as the object flew away towards the horizon, Frégnale, who had taken his binoculars, saw it "disintegrate" and disappear on the spot. For that reason, he assumed that it was "agglomerated cosmic dusts" (which is complete nonsense for any astronomer or meteorologist).

Some years later, I obtained the original negatives. There were actually four 24×36 images, taken successively on a black and white negative film. They were preceded and followed by images having no relation with the UFO photographs. Therefore, there were no successive attempts to get "good" photographs of the object, nor "failures." For me this was a strong argument against a forgery, although it was not yet a proof. I critically analyzed the four

[1]This book has been published in America under the title "The truth about flying saucers." It seems Frégnale did not want his photographs published without copyright. Thus, he had left copies of them to an agency which was in charge of distributing them. The standard of living of retired engineers during years just after the Liberation was not as it is now, so I think Frégnale's behavior does not argue against the authenticity of the photographs.

negatives with a microscope, which made me *certain* of the absence of any alteration or natural photographic artifact like a reflection, development marks, etc. These were images of an *outside object* formed on the film through the camera lens. Moreover, these images *could not result from intentional superposition* (by use of a two-way mirror or other means), because such a trick would not leave on the negatives dark details of the foreground trees completely underexposed and the lower side of the UFO partially underexposed. Hence, the photographs actually showed an object in the sky, but what kind of an object?

With great care, I made enlarged copies of the four images in my laboratory of the Institut d'Astrophysique, including the margins of the 35 mm negative film, using an excellent magnification lens. This lens gave very sharp images with no geometric distortions, such that all the details contained in the original negatives were on the copies. However, the photometric data were necessarily altered due to the non-linearity of the photographic curves. (However, since the original negatives were not calibrated *before* development, quantitative luminance measurements were impossible, even with the original negatives.)'

In 1972 I used these images to illustrate a paper on UFOs, which was published the same year in the September issue of the French magazine *Science et Avenir*. At that time I drew the reader's attention to the presence of an oblong black spot on the lower dark side of the disk. At first glance, this spot seemed pointed *in a direction opposite to the alleged movement of the object on the four images,* changing progressively with the perspective effect from a horizontal position to an inclined one towards the top right, as the object "went down" towards the horizon at the left. But it is only recently, at Joel Mesnard's suggestion, that I undertook to mathematically test this apparent property. Study of the images convinced me that a detailed analysis would reveal much more information than a brief examination could.[3] One then only has to compare the numeric data obtained from the images to a geometric model of the trajectory based on the witness's statements. The deductions drawn from this modeling appeared to be predictive, in agreement with the computations made from the measurements done on the shots. This procedure has provided the proof of the authenticity of the photographs; the UFO geometrically behaves like a distant flying object traveling on a straight horizontal trajectory, always keeping some inclination to the ground, and not like a model oscillating at the end of a wire or thrown into the air four consecutive times.

[2]Once this work was finished, I returned the original negative roll of film to the person who had lent it to me and who then gave it back to Frégnale. Recently, I learned that the roll of film stayed in his hands until he died about ten years ago. Frégnale was single and lived with his sister who was single also. I was able to get the present address of this woman, who is now very old. It seems she still has the material left by her late brother, but says she is too tired to search for them in the box where they have been placed. The original negatives of the Lac Chauvet UFO will probably be thrown away when the old woman dies, even if heirs are defined. So I had to be content with working on my copies of these negatives, which on my honor as a scientist, have not been altered.

[3]A French ufologist, editor of the French journal of ufology Lumières dans la Nuit.

The Witness Account and the Photographs

Date :	July 18th, 1952.
Time :	18:10 (local time) (17:10 GMT)
Place :	near Lac Chauvet, 7 km south of Puy de Sancy (extinct volcano) departement of Puy-de-Dome, France.
Weather :	very fine, blue sky, wind directed towards north-west at an altitude of 3000 m, toward west at ground level (speed: 60km/h) (from the French *Météorologie* Nationale).
Sun position :	altitude 22°, azimuth 97° west.

Trajectory of the object: from west to east (from right to left for the witness facing the south). The object had been noticed coming from the right just before reaching its largest angular height to the south. The witness immediately took two photographs when the object was near this largest angular height (Photographs I and 2), and then took two other photographs when the object was moving away to the left, going down towards the horizon due to the perspective effect (Photographs 3 and 4). As the object's angular dimensions became smaller and smaller, the witness used his binoculars to view it and, shortly after, saw it disappear mysteriously, as if it had vanished on the spot. The observation only lasted about fifty seconds, and the witness thought that the object's azimuth covered about 100 degrees during this time. The trajectory was "horizontal and straight," the linear speed was apparently "constant," the movement uniformity was "impressive, without any swinging or sinuosity in the trajectory," and there was a "total" silence.

Description of the disk: a circular object seen obliquely from beneath (ellipse), "without any protrusion: no antenna, neither porthole nor propeller (sic), no presence of smoke or hot gas." The visible side (lower side) was dark, "with an undefined color, metallic gray or gray-green." A darker oblong and eccentric spot was visible under the disk, like (under the hypothesis of a driven machine) a slightly swollen "nacelle" or "cockpit." The witness saw, with his binoculars, a "cut" in front of this "cockpit," and another one at its rear.

The photographs: according to the witness, 25 seconds were taken to shoot the photographs, with about 8 seconds between consecutive shots. (One can suppose that this time interval should have been shorter for the two first shots than for the last two, since the object's angular speed decreased with distance under the hypothesis of a constant linear speed.) The film: Kodak Panatomic-X 35 mm. The developer type: modified Kodak D-25 (with genol-sulfite boric acid). The bath was old, so the development was prolonged. The camera: Zeiss Ikonta with an excellent Tessar lens (with a 45 mm focal distance) and with a central shutter of Compur or Prontor type. A slightly yellow filter Wratten 15 was used (to darken blue sky on black and white photographs). The diaphragm was likely set at 1:5.6. The displayed exposure time was 11250 s (but likely 1/200 s, since central shutters are always too "slow" at high shutter speeds). Considering the average photographic density which varied on the negatives, the diaphragm (or the speed?) was changed between the first and second shots.

The four images, taken successively, are numbered 3-3a, 4-4a, 5-5a and 6-6a on the film margins. We shall label them 1, 2, 3 and 4, respectively. Images 1 and 2 were taken with the camera raised towards the sky and held "horizontally," images 3 and 4(which show clouds near the horizon and a little grassy hillock in the foreground, respectively) with the camera held "vertically."

On each image the oblong black spot under the object is clearly visible, but it does not resemble a "cockpit," even a flattened one.[4] On the other hand, no slit is visible, either in front of or at the rear of the spot. The shape of this structure is identical on the four photographs and obeys the laws of perspective. This contradicts an interpretation involving a shadow cast by something under the object. Moreover, the lower side of the disk cannot be illuminated by sunlight, because of its slight inclination towards the north (see below) and of the altitude of the sun above the western horizon. For these reasons, the oblong black spot under the disk appears to be a permanent structure located on its surface.

In addition, we can clearly observe a shiny edge which is on the upper and right part of the disk. This apparently results from the reflection of sunlight on the side of the object, considering the alleged position of the sun with respect to the images.

A First Analysis of the Images

We are fortunate to have four successive photographic images on a very fine-grained emulsion taken by means of an excellent optical system, which should contain considerable information. Unfortunately, the photographic situation was not ideal for photographs that are to be scientifically investigated. First, there is the question of the ellipse inclination to the horizon on the four images, since the horizon is not visible on them–it is true that the field of view of the lens is not sufficient to include the horizon, at least for the three first shots. Next, images 1 and 2 are not sharp because of motion, particularly the first; the oval image of the UFO is stretched along its major axis, as if the object moved from right to left during an overly long exposure time. Actually, this lack of sharpness is due to the photographer's motion, not to that of the object; according to Frégnale, the disk was moving rather slowly, and the exposure time selected should have frozen the image on the film. Moreover, we note that the stretching of the image is not exactly parallel to the major axis of the ellipse on shot 2. Most importantly, we can see that the same image stretching is also visible in the details of the tree at the right of the field. It seems that the photographer, trying to do his best, tried to "follow" the object along its trajectory when he opened the shutter, and did so in a jerky way. The

[4]However, we note that this spot is more complicated than a simple dark strip: we can distinguish a central round spot extended to the right by an oblong, slightly curved tail. Hereafter, when we refer to the axis of the spot, we mean the axis of the strip made with the central spot and the tail.

result of this awkwardness is that the ellipse major axis length is difficult to measure with great accuracy on shot 2 and almost impossible on shot 1.

Minimum distance of the object: On the other hand, images 3 and 4 are perfectly in focus. The saucer stands out against the sky, the lack of sharpness of the image edges (visible at very high magnification) is about 1/100 mm, which approximately corresponds to the resolution limit of Panatomic-X film for contrasted details. The focus on the object was thus perfect, and as the contours of the clouds visible at the bottom of shot 3 are also very sharp, we can deduce that the camera was focused on infinity. An independent test confirms this fact: on Photograph 4, details of the tree branch which "directs" towards the UFO are a little less sharp than for the UFO and the grass of the foreground little hillock is "smoothed" by an evident defocus. We can trust the photographer when he declares that the diaphragm he used was 1:5.6 because, for a focal distance as small as 45 mm, all the details of the landscape would have been equally sharp if the diaphragm opening had been smaller.

This fact allows us to estimate, by a simple computation of the depth of focus, the minimum distance to the object, under which a slight alteration of the sharpness of its contour will be visible. We find this distance to be about sixty meters! Since the object subtends an angle on the sky of about 1° on average, in the case of a hung model this implies a disk at least 1 m in diameter hanging at the end of an invisible wire from a crane (out of the field of view) at least 50 m high. I will let the reader judge this possibility. In fact, the object was much further than this minimum distance. Its contrast with respect to the sky on the copy of the original negative film is qualitatively less on image 4 than on image 2 (these images being equally exposed to the sky). This suggests that a light atmospheric mist or fog was present. However, the weather was dry and nice, and for such a mist to be noticeable, the distance should have been at least about one kilometer rather than 100 meters. Another argument in favor of a large distance to the object is that the witness viewed it with binoculars which he did not have to focus nearer than infinity to see the UFO distinctly.

Direction of the horizon: Although the horizon is not visible on all the images, one of them allows measurement of the horizon line direction with great accuracy (about 0.5"). This is Photograph **3,** where one sees cumulus clouds at the lower part, the bases of which appear, with the perspective effect, like parallel horizontal lines. (The horizon cannot be lower.) The angle made by these lines with the minor side of the 24 × 36 rectangle is **3".** This figure is not surprising since most amateur photographers do not hold their camera in the "right" position, especially without a reflex system.

On Photograph 4, the horizon is apparently hidden by the little grassy hillock in the foreground, the ridge of which is inclined at an angle of about 5° to the minor side of the 24 × 36 rectangle. The inclination has the same direction as on Photograph 3 and may demonstrate a systematic tendency of the photographer to tilt his camera in the same way. However, it is obviously risky to choose the value of 5° rather than another close value, since there is no reason for the ridge of the little hillock to be perfectly horizontal. (Nevertheless a value of 5°

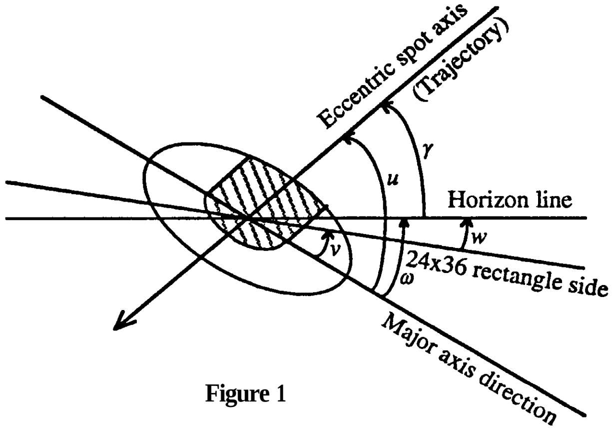

Figure 1

is consistent with the angle at which the image should be rotated for the grass blades on the little hillock to be vertical on average). For now we will use this value, subject to modification later if it leads to obvious incompatibilities.

Although it is impossible to determine where the horizon is on images 1 and 2 without some assumption, a method does exist to resolve the ambiguity. At first it seemed that the photographer stayed almost exactly at the same place when taking the two photographs, because of the details of the tree at the right, which are seen at nearly the same angles. On the other hand, it is clear that the photographer did not hold his camera in the same manner. Even if one takes into account the converging of the vertical lines upwards when the camera is directed towards the sky, it is obvious that the tree is not inclined in the same way on the two images. But it is known that straight lines should remain straight on the photographs.[5] If one draws a line between the axis of the eccentric spot on the UFO and the tree on each of the two photographs, one observes that these two lines will strike the tree at almost the same place. These two lines in fact almost merge and apparently represent part of the object's trajectory, which is directed along the axis of the eccentric spot as is clearly seen on the composite photograph of images 1 and 2. However, according to the witness, the object was moving along a straight horizontal trajectory, from right to left; thus, the part of the trajectory just drawn can be considered to be approximately parallel to the horizon, the camera being directed southward.

As one can see, we took the photographer at his word, allowing us to use the model based on his statements to reveal inconsistencies and to discover if the model would be invalidated by the measurements.

[5]At least with a constant focal length lens like a Tessar. This property is not rigorously verified with a zoom, which almost always produces a geometric distortion like a pincushion or a barrel, depending on the focal length.

The Measurements

On the four images, the disk is seen like a flattened ellipse (Fig. 1), of which the major axis 2a and the minor axis 2b can be measured. (The flatness is the ratio b/a.) On images 2 and 3, it is also possible to measure the angle u that the eccentric spot makes with the major axis, and the angle v that the minor side of the 24 × 36 rectangle makes with the major axis. If the inclination w of the horizon to this minor side is known, one can derive the angle ω of the major axis, and also the angle y of the eccentric spot, made with the horizon by:

$$\omega = v + w,$$
$$\gamma = u - \omega.$$

For ω and y we will need to compute the object's angular height α above the horizon, as will be shown later.

On photograph 2, one can notice the angle u is not zero, although it is small. It can be estimated at about 4°, but it is impossible to estimate the weight ofω and y in this spot inclination to the major axis. The camera is approximately directed southward and not towards the object, the apparent trajectory being thus horizontal. It would cease to be such and would begin to tilt slightly downwards to the left (like on the following photographs) if the camera were to have been directed eastward so as to bring the object exactly at the field tenter, allowing measurements of this apparent inclination. However, it is not possible here.

Similar comments can be made concerning Photograph 1, on which the lack of sharpness due to motion is such that the two ends of the major axis are "clipped" on light prints. But if measurements are made on dark prints, which show the complete spreading of the lack of sharpness (including the shiny edge at the right which is greatly widened), one can well define the major axis direction, thus demonstrating that the angle u it makes with the eccentric spot is reversed, its value being between about 13" and 17".

The evaluation of the major and minor axis lengths can be made with good accuracy on images 3 and 4, but one must take into account the small deformation of the ellipse by the shiny edge, at the top right, whose light overlaps onto its contour due to photographic diffusion. On the other hand, lack of sharpness due to motion on photographs 1 and 2 makes the major axis measurement difficult on Photograph 2 and uncertain on Photograph 1. However, despite these uncertainties, the major axis seems a bit smaller on Photograph 1 than on Photograph 2 (this appears on all the prints, the dark ones and the light ones). Thus, the object's position when closest to the witness should be between positions 1 and 2, and closer from position 2 than from position 1. However, the minor axis, which can be measured on both images, is slightly greater on position 1 than on position 2, implying that the ellipse is more "opened" (the disk is inclined with a greater angle towards the witness).

The raw data (done on magnifications, all at the same scale)have then been corrected for the geometric deformation inherent in the photographic process;

i.e., if d is the angular distance of the object from the photographic field center, the image is lengthened in the transverse direction by the factor 1/cos d, and in the radial direction by the factor $1/\cos^2$ d. This effect is particularly sensitive with large-angle lenses. In the present case, d being about only 10°, the deformation is small but not negligible.

The inclinations of the ellipse and of the eccentric spot are more difficult to measure exactly, particularly the angle *w* on Photograph *4* (because of the small length of the eccentric spot on this image) and even more on Photograph 2 (because of the lack of sharpness). Corrections to raw data are useless here, considering the relative inaccuracy of the measurements.

The values used for the data processing are given in the Table below. The lengths $2a$ and $2b$ are in mm and correspond to their values on the original negatives, after computation of the measured values on the enlarged prints. The errors given correspond to the maximum errors in the measurements.

Geometrical Parameters for the Four Photographs

Photograph	Row Data	Corrected Data	Angular Diameter	Flatness b/a	ω	γ
4	$2a_4 = 0.544 \pm 0.015$	0.535 ± 0.015	0.68°	0.516	9° ± 1°	41° ± 3°
	$2b_4 = 0.286 \pm 0.015$	0.276 ± 0.015				
3	$2a_3 = 0.751 \pm 0.015$	0.743 ± 0.015	0.95°	0.697	4° ± 0.5°	26° ± 1.5°
	$2b_3 = 0.528 \pm 0.015$	0.517 ± 0.015				
2	$2a_2 = 0.873 \pm 0.025$	0.840 ± 0.025	1.06°	0.820	$\omega + \gamma = 4° \pm 0.5°$	
	$2b_2 = 0.702 \pm 0.015$	0.689 ± 0.015				
1	$2a_1 = 0.845 \pm 0.30$?	0.828 ± 0.03 ?	1.05°	0.857 ?	$\omega + \gamma = 16°^{+1°}_{-3°}$	
	$2b_1 = 0.720 \pm 0.015$	0.710 ± 0.015				

Modeling

The witness described a disk which was moving with steady speed from west to east on a horizontal trajectory, which made it appear to lower towards the horizon to the east due to the perspective effect. This disk was seen as an ellipse, the analysis of the photographs showing this ellipse inclined to the horizon at an angle ω which increased as the object moved away. This fact can be simply explained in the following way, which is suggested by the alleged absence of any swinging of the object: *the plane defined by the lower side of the disk (the visible side) is inclined northwards to the horizontal plane at an angle Ω, around an axis which is the trajectory.* When the disk is exactly due south, at its smallest distance from the witness, its lower side is rotated towards him at the angle Ω, and the ellipse appears more "opened" than if the disk were flying "flat." But the witness had no way of noticing this, because the UFO did not tilt to the left or to the right. Then, as the disk moved away westward (Photographs 3 and 4), its lower side, still rotated northward at the angle Ω (i.e. towards the left), appeared more and more inclined, the apparent inclination remaining less than Ω (except if the disk were seen at infinity by its side).

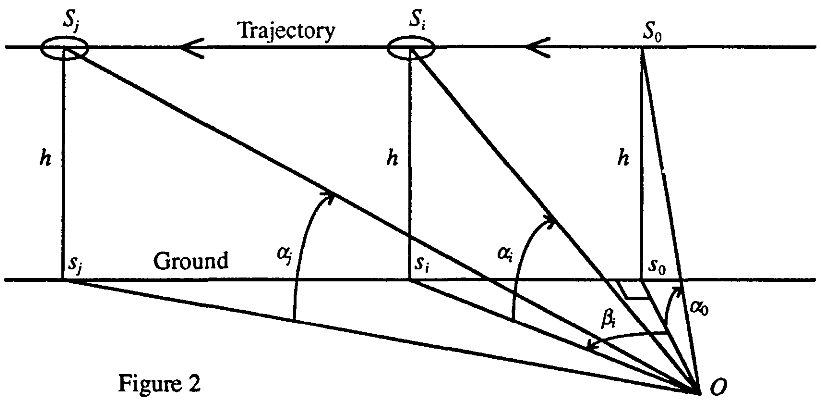

Figure 2

The eccentric spot is aligned with the trajectory on Photographs 1 and 2, and we will assume this is still true on Photographs 3 and 4. This assumption is supported by the fact that it rises towards the right along with the apparent trajectory tilts downwards to the left. *The axis* qf *this spot, which makes the angle γ with the horizon on the photographs, thus gives, under this hypothesis, the apparent trajectory direction on each image.*

This is the simple model which will be used and tested numerically.

We first find the equations which express that the trajectory is horizontal.

I. *Relation between the angular height and the object apparent diameter.* One has (Fig. 2) :

$$h = \text{Constant} = OS_i \sin \alpha_i = \text{OS}, \sin \alpha_j,$$

and thus :

$$\sin a_i = \frac{OS_i}{OS_j} \sin \alpha_i$$

However, the ratio $OS_i\ /OS_j$ of two distances from the object to the witness equals the inverse ratio a_j/a_i of the two respective apparent dimensions of the ellipse major axis, those subtending small angles (about 1°). Thus:

$$\sin a_j = \frac{a_j}{a_i} \sin \alpha_i \qquad (1)$$

2. *Formula giving the azimuth and the angular height depending on the maximum angular height at the closest position.* This azimuth β_i is measured from the direction *Os,* of the closest position. Fig. 2 gives:

$$Os_0 = \text{hltan } \alpha_0,\ Os_i = \text{hltan } \alpha_i,\ \cos \beta_i = Os_0\ /Os_i,$$

and thus :

$$\cos \beta_\text{i} = \frac{\tan \alpha_\text{i}}{\tan \alpha_0} \qquad (2)$$

3. *Formula giving the apparent inclination γ of the trajectory to the horizon.* The witness looks at the object in ***S*** (Fig. **3).** The apparent trajectory, parallel to

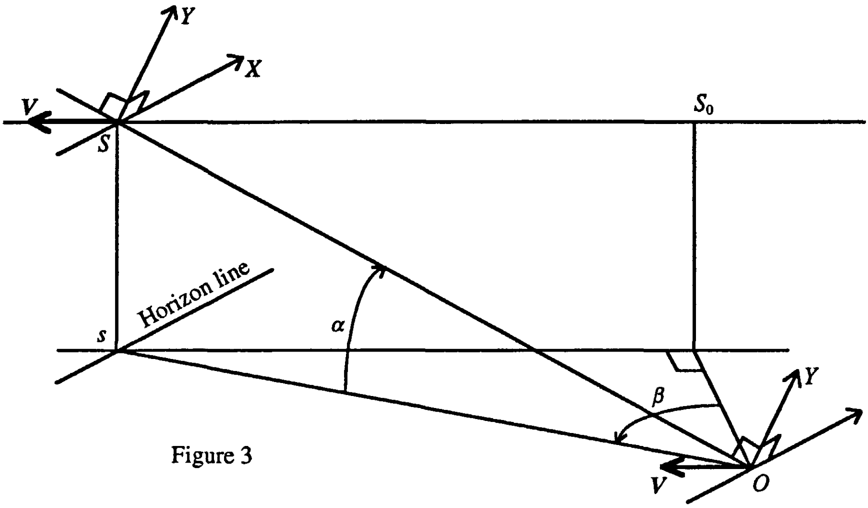

Figure 3

the speed vector V, is inclined at the angle y to the horizon, due to the perspective effect. This inclination will be measured with respect to the line SX parallel to the horizon in an orthonormal axis system SXY perpendicular to the sight direction line OS. We undergo the translation SO to this system and to the vector V. One sees then that V makes with OX (in the horizontal plane) an angle n–b, its projection V_X on OX (and thus on SX) is thus–V cos b. Moreover, V makes with *Os* (still in the horizontal plane) an angle π/2–b, its projection on *Os* is thus Vsin b, and since *Os* is inclined (in the vertical plane) at an angle π/2 + a to OY, the projection V_Y of V on OY (and thus on SY) is finally :

$$-V \sin \beta \sin a.$$

For the witness who looks at the point S, the tangent of the trajectory apparent inclination y is given by V_Y / V_X, that is to say:

$$\tan \gamma = \tan \beta \sin a. \tag{3}$$

We now find the equations which take into account the disk inclination to the horizontal plane.

1. Angular height of the disk depending on ***a***, β, ω and γ. If the disk were flying "flat" (Ω = 0), the ellipse axis ratio b'la observed would be the cosine of the angle between the disk plane and the plane perpendicular to the sight line. The complement of this angle would give the object angular height a. But the disk is not flying "flat" and the angle Ω it makes with the horizontal plane is not known. However, one is able to compute b'la from the observed ellipse axis ratio *b*/*a* , in the following way :

Since the disk is inclined about the axis AB (Fig. 4), the "straightened" ellipse to be seen if it were flying "flat" passes also through A and B. In the axis system Sxy, the point A is on the line SA, the equation of which is :

$$y = \tan (\omega + y) \cdot x.$$

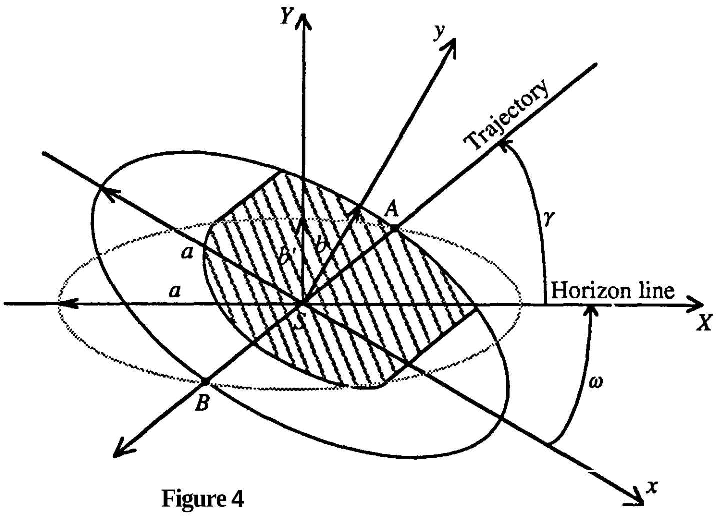

Figure 4

It is also on the observed ellipse, the equation of which is :

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1.$$

The coordinates (x_A, y_A) of the point **A** are thus given by :

$$x_A = \left(\frac{1}{a^2} + \frac{\tan^2 (\omega + \gamma)}{b^2} \right)^{-\frac{1}{2}},$$

$$y_A = \tan (\omega + \gamma) \cdot x_A.$$

In the straightened axis system SXY, the point ***A*** has the coordinates :

$$X_A = x_A \cos \omega + y_A \sin \omega,$$

$$Y_A = y_A \cos \omega - x_A \sin \omega.$$

But **A** belongs also to the straightened ellipse, the equation of which is :

$$\frac{X^2}{a^2} + \frac{Y^2}{b'^2} = 1 \text{ (a is not changed)}$$

from which we deduce :

$$\frac{b'}{a} = \frac{Y_A}{\sqrt{a^2 - X_A^2}}$$

and $\alpha = \pi/2 - \cos^{-1}(b'/a)$ (or $a = \sin^{-1}(b'/a)$).

It is easy to program these computations, but it is also possible to get the relation which directly gives a. Let r = bla be the flatness. One finds, from the previous relations, that :

$$\tan\alpha = \frac{r}{\sqrt{1-r^2}} \cdot \frac{\sin y}{\sin(\omega + y)'} \qquad (4)$$

2. Formula giving the inclination Ω of the disk plane to the horizontal plane depending on ω and β. After some algebraic manipulations, it is possible to show that :

$$\sin\Omega = \sqrt{1-r^2} \cdot \frac{\sin\omega}{\sin\beta} \qquad (5)$$

Numerical Application

The model can now be tested. Photographs 3 and 4 are the sharpest ones and ω and γ can be measured separately on them, and also a and b, with a rather good accuracy. By putting the derived values (see the Table) in Eq. (4), one finds[6] :

$$a_3 = 40.3°\pm1.1°,$$

$$a_4 = 27.3°\pm1.1°,$$

These results are thus compatible with the supposed position of the horizon on Photographs 3 and 4.

We first verify if the trajectory is horizontal between positions **3** and 4. By the use of Eq. (1), one can compute α_4 from α_3 (which is the angular height measured with the greatest relative accuracy), giving:

$$\sin a, = \frac{0.535}{0.743}\sin 40.4° = 0.466$$

$$\alpha_4 = 27.8°.$$

The agreement is excellent, *the trajectory remains thus horizontal between positions 3 and 4*. This encourages to compute α_2 with Eq. (1). One finds :

$$a_2 = 47.05°.$$

One can verify whether this value a,, computed by assuming the trajectory is horizontal, is compatible with the value of u on image 2, which is estimated to be about 4". Since $u = \omega + y$, and since ω is always less than y, we will make, as a trial, the hypothesis : $\omega_2 = 1°$, $\gamma_2 = 3"$. We compute α_2 from these values. One finds :

$$a_2 = 47.1°.$$

The excellent agreement is somewhat illusory, as the exact values of ω_2 and γ_2 are not known, and the standard deviation is at least 3" for $\alpha 2$. It can only be assumed that the estimate of the angle u made on image 2 is *compatible with the hypothesis the trajectory* **is** *horizontal between positions 2 and 3.*

[6] The given error bounds are estimates of standard deviations.

The determination of the angle a, still remains. It can be deduced from Eq. (1) as done for a,,, and one finds:

$$\alpha_1 = 46.15°.$$

This value is compatible with the estimation done of u,, if $\omega_1 = 6"$ and $\gamma_1 = 10°$, in which case computations which make the disk to be "flat" give ***a*,** = 46.3".

Computations of the disk azimuth and *of* its inclination to the horizontal plane. The complement of the angle α_2 computed above in two independent ways, is 42.95"; it is the angle that the disk would make with the plane perpendicular to the sightline if the saucer were flying "flat." The observed ratio r_2 is 0.820, which corresponds to an actual inclination of 34.9" .The difference between the two angles gives an estimate of Ω_2, since the object at position 2 is not far from its closest position. Thus:

$$\Omega_2 \approx 8°.$$

By means of Eq. (5), we compute the azimuth β_2 with Ω_2 just determined, and with ω_2 evaluated to be 1°. One finds:

$$\sin\beta_2 = \sqrt{1-0.82^2}\,\frac{\sin 1°}{\sin 8°} = 0.72,$$

$$\beta_2 = 4.1 \approx 4°.$$

This result shows that the object had just passed through the closest position when it arrived at position 2, thus explaining why the angle of the ellipse major axis with the trajectory seems to be the opposite on image 1. As an example, it is possible to measure the trajectory arc between positions 1 and 2 on the composite photograph; it is about 12°. This corresponds to an azimuth variation at ground level of 12" /cos α, a being the object's average angular height (47°). In this way we find an azimuth variation of about 20 degrees, which proves that the object, at position 1, was at a west azimuth of about 16°.

One can now compute the angular height α_o of the object when it is at the closest position, along with the object's azimuths at positions 1, 3 and 4. Eq. (2) may be written: $\tan\alpha_0 = \tan\alpha_i/\cos\beta_i$. Taking $\alpha_2 = 47.1°$ and $\beta_2 = 4.1°$, one finds: $\tan\alpha_0 = 1.079$ and thus $\alpha_0 = 47.17°$. This value of $\tan\alpha_0$ will permit the computation of the azimuths β_1, β_3 and β_4 from a,, a, and a, by means of Eq. (2):

$$\cos\beta_1 = \frac{\tan\alpha_1}{\tan\alpha_0} = \frac{\tan 46.15°}{1.079} = 0.965,$$

$$\beta_1 \approx 15° \text{ (to the west)},$$

which confirms the value found above from the angle measured between positions 1 and 2. One then finds:

$$\cos\beta_3 = \frac{\tan\alpha_3}{\tan\alpha_0} = \frac{\tan 40.3"}{1.079} = 0.786,$$

$$\beta_3 \approx 38°,$$

$$\cos \beta_4 = \frac{\tan\alpha_4}{\tan\alpha_0} = \frac{\tan 27.3'}{1.079} = 0.478,$$

$$\beta_4 \approx 61.5''.$$

Putting these values of β_1, β_3 and β_4 in Eq. (5), one gets

$$\Omega_1 \approx 12°, \Omega_3 \approx 5°, \Omega_4 \approx 9°.$$

This value of Ω_4 is compatible with the measured value of ω, the error bounds being taken into account. The disk inclination to the horizontal plane has thus not been kept constant along the trajectory, its value being between 5° and 12°, a difference which the witness (who had not observed the object swinging) obviously would not have noticed.

Computation of the apparent trajectory inclination to the horizon. The values of the azimuth b we have just computed will allow us to find the angle y of the apparent trajectory to the horizon on images 1, 3 and 4, by the use of Eq. (3). One finds in this way $\gamma_1 = 11$ (instead of the supposed value of 10" for the eccentric spot inclination), $\gamma_3 = 26.9°$ (instead of the measured value of 26°), and finally $\gamma_4 = 40.1°$ (instead of the measured value of 41"). The agreement is still excellent between the results deduced from the model and the measurements on the photographs. The alignment of the eccentric spot with the trajectory is thus confirmed, which validates *a posteriori* the value α_0 which is used in the azimuth computation.

Conclusion

These extraordinary photographs of the Lac Chauvet "saucer" are used for measurements and a detailed analysis which suggests a simple trajectory model that is compatible with the witness's testimony. We have demonstrated that the photographs showed a disk-shaped object located at a large distance in the sky and, thus, having large dimensions. This model is validated by good agreement between the numerical results one can deduce from it, and the measurements on the images. The disk was flying along a straight and horizontal trajectory, keeping an inclination to the horizontal plane, about the axis trajectory and at an angle which remained between about 5° and 12°. The eccentric spot remained aligned along this axis during the observation, which makes unlikely the possibility of a forgery by means of a model hung at the end of a wire or thrown into the air.

A single UFO photograph is almost impossible to authenticate without relying on the testimony of the person who has taken it. We may thank the witness for having taken four shots consecutively. In addition, the high quality of the Tessar lens, the landmarks given by the trees and the clouds, and the uniform and easily analyzable trajectory without zigzagging motion have aided the analysis. This series of photographs by themselves are sufficient to prove their authenticity. Such a proof might be more difficult to achieve for photographs obtained with modem methods. But in 1952 there was no possibility of forgery with computer technologies and digitization of images.

Finally, if the disk were about 15 meters in diameter, a common dimension for the "flying saucers" of that time according to the estimates of numerous observers, the reader can easily compute, with the data given in this paper, the trajectory height above the ground (assumed to be horizontal) would be - 590 m; the smallest distance of the saucer to the witness - 800 m; the trajectory length, covered in 25 s, between shots 1 and 4, - 1160 m; and the average speed - 170 km/h.

Finally, if the object had the dimensions just calculated-even if it were only 9 or 10 m in diameter-its speed would then significantly exceed the wind speed (60 km/h) which was blowing from the west at this altitude. *It was thus necessarily self-propelled,* and was not pushed by the wind as a balloon would have been.

Acknowledgments

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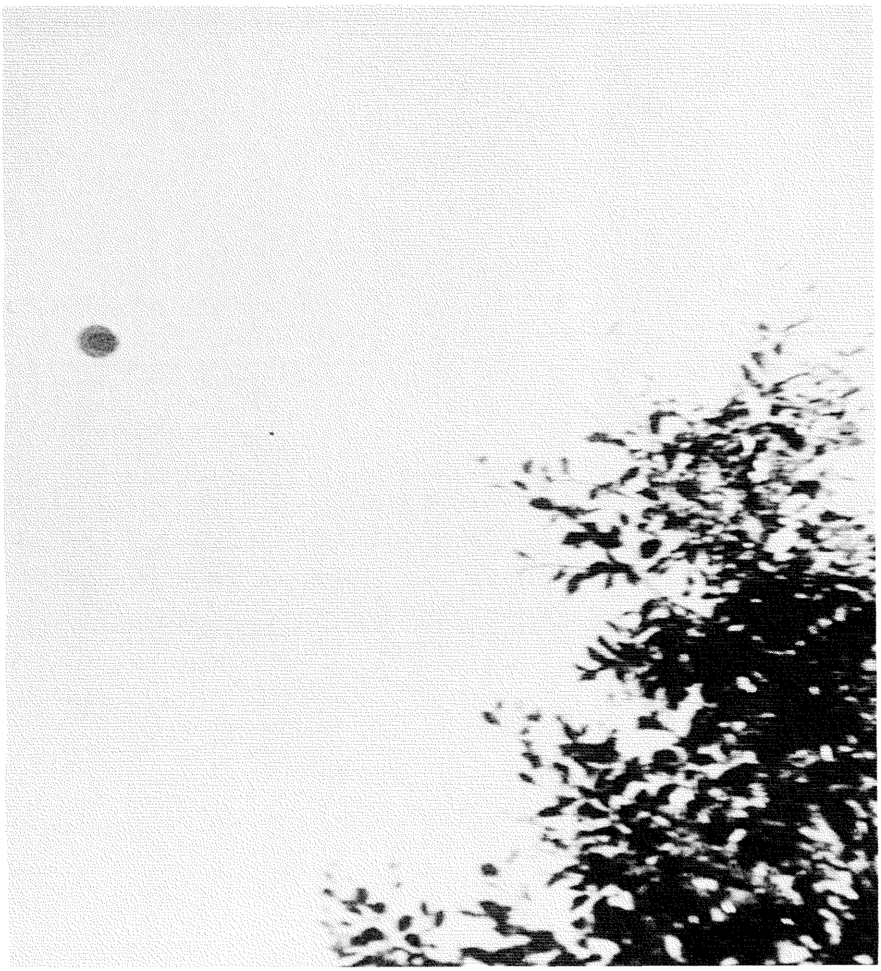
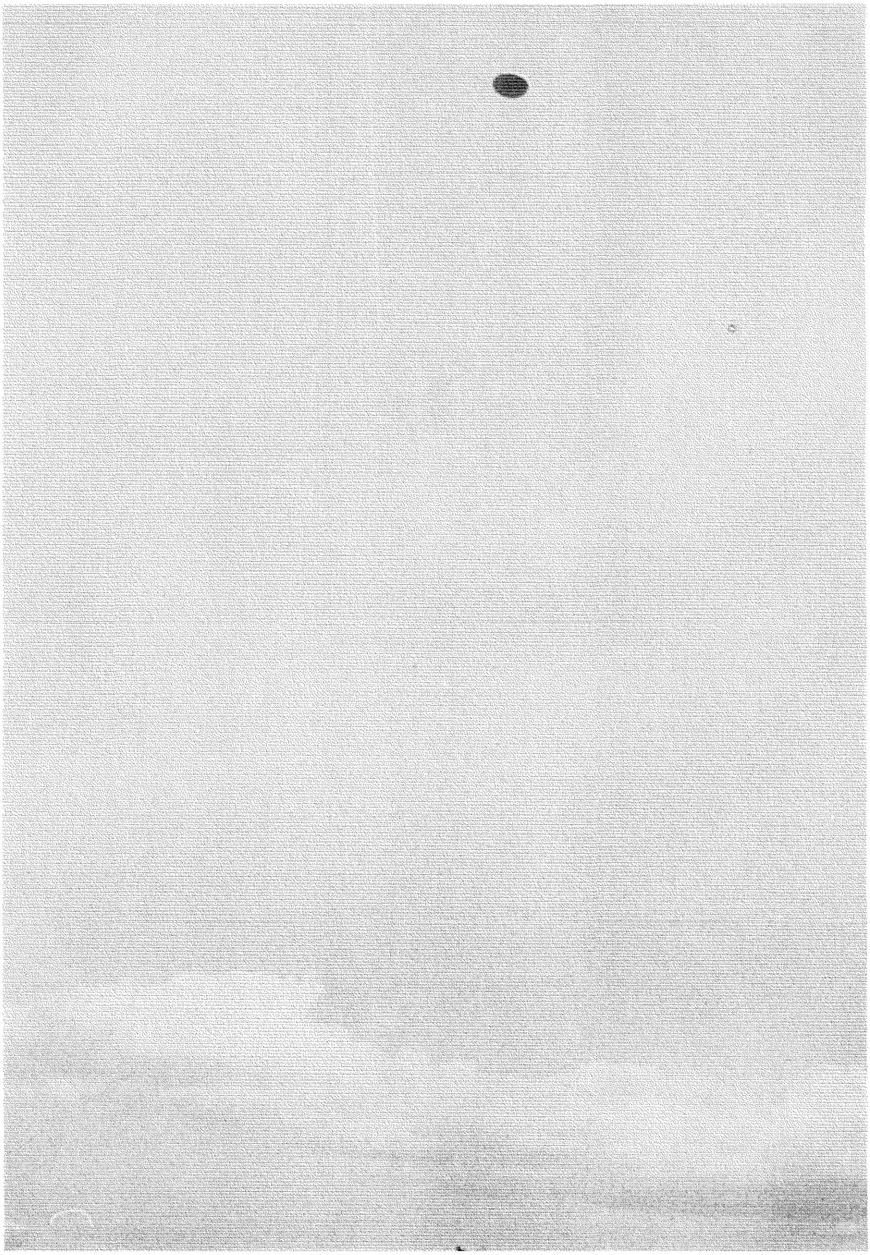
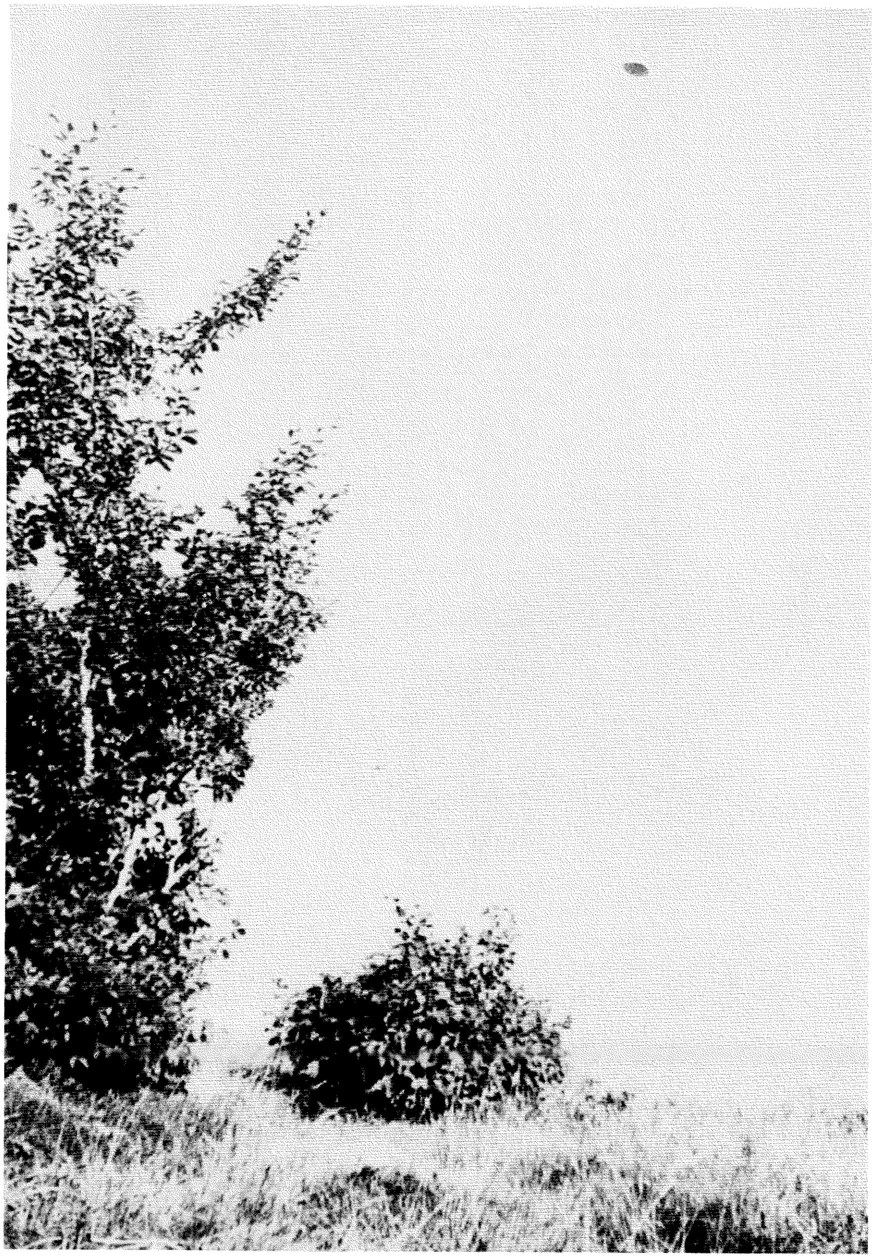


Photograph 1.

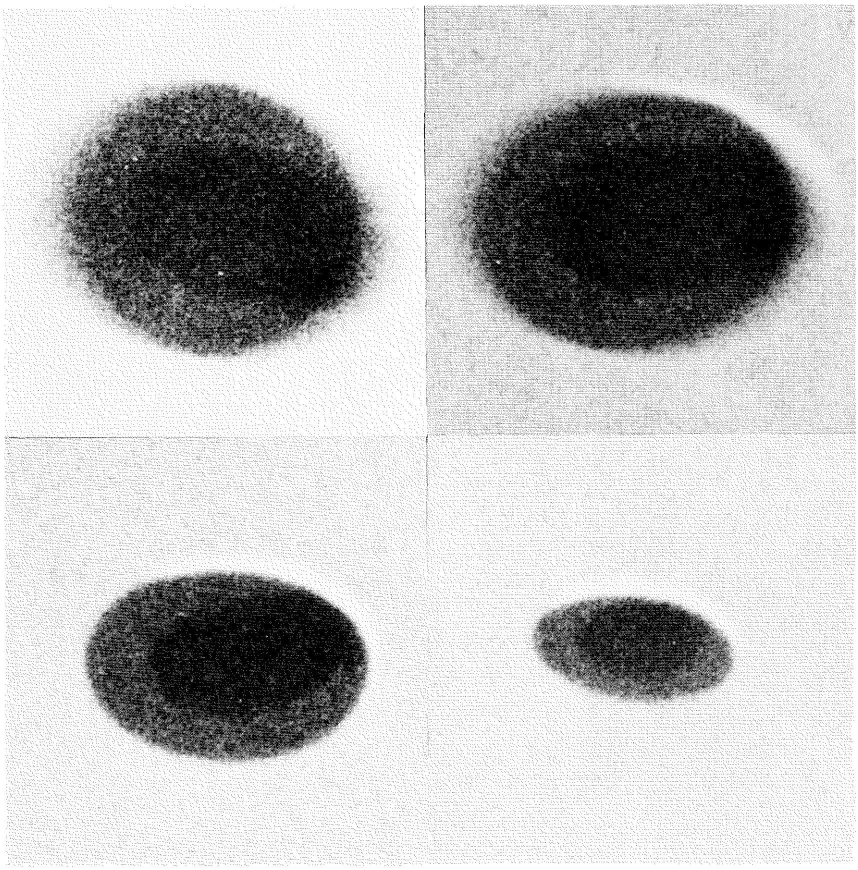
Photograph 2.



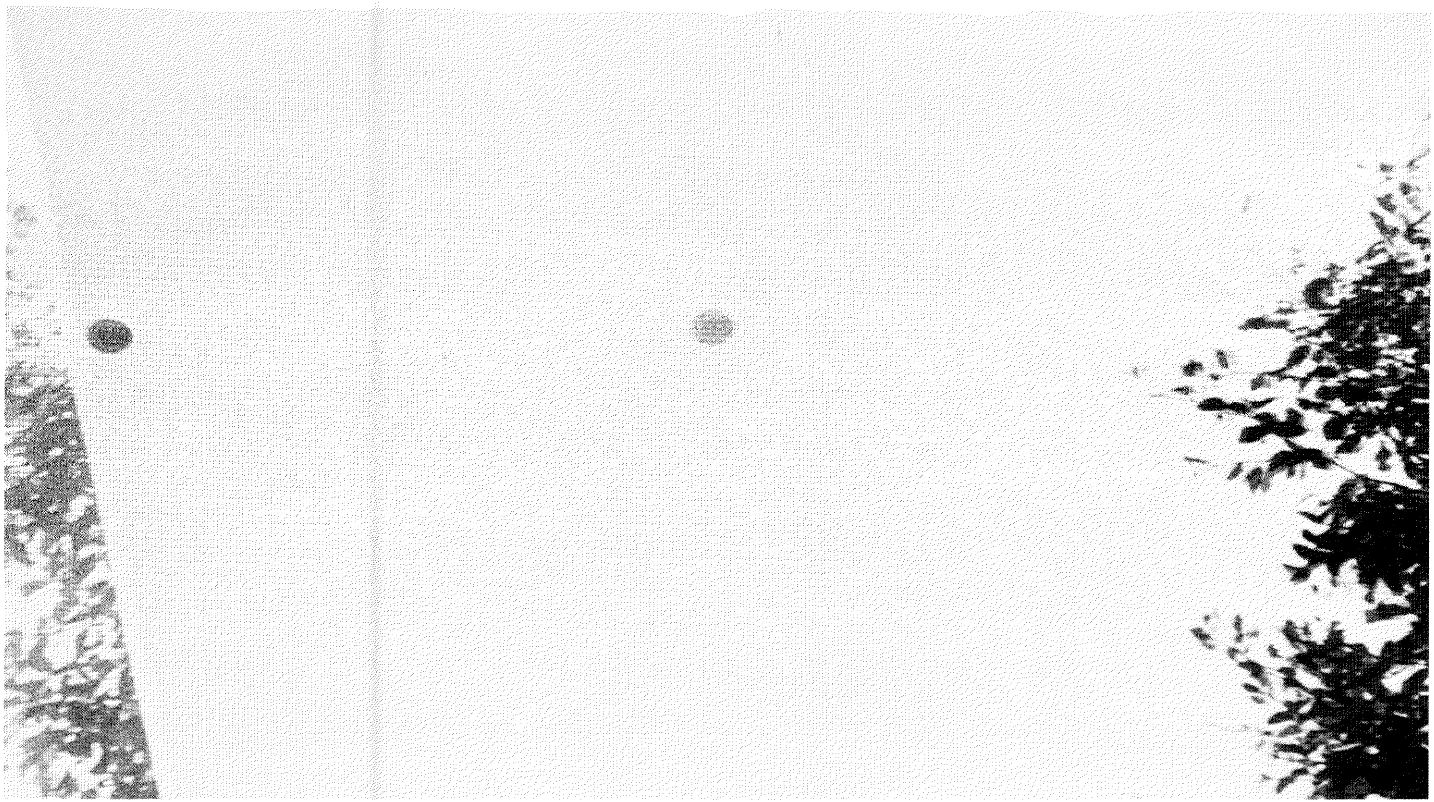
Photograph 3.



Photograph 4.



Enlargement of photos 1–4.



Composite photograph of photos 1 and 2