present, thunderstorm activity was considered possible, even though this technique clearly overestimated actual activity. When these assumptions were made, only 22.5% of the sightings involved nonsilver objects, possible thunderstorm conditions, and occurred at night. It was assumed that a description of the phenomena as silver, fair-weather conditions, or daytime observations precluded the coronal explanation (because the coronal discharges are not silver, and not very bright). A majority of the sightings, 58.8%, took place on clear days or nights, or involved silver objects. Approximately 19% of the sightings involved insufficient information for adequate synoptic analysis.

I do not support any particular hypothesis for the Utah UFO sightings; I simply wish to point out that in most and probably all cases, spruce budworm or other insects were not creating significant optical phenomena. Callahan and Mankin's paper[1] has been widely cited as a new plausible explanation for UFOs in such sources as *Time*[11] and the BBC World Service (short-wave radio broadcast).[12] The information and hypotheses forwarded in this Letter clearly demonstrate the inadequacy of the Callahan and Mankin hypothesis; unfortunately, the general public probably now believes their hypothesis to be a well-grounded theory or even fact. Entomologists should not use UFO reports to indicate insect migrations (as suggested by Callahan and Mankin[1]), because UFO reports probably do not involve swarms of coronal insects.

References

1. P. S. Callahan and R. W. Mankin, Appl. Opt. **17**, 3355 (1978).
2. R. Gunn, J. Appl. Phys. **19**, 481 (1948).
3. A. Kamra, Nature **240**, 143 (1972).
4. J. C. Johnson, *Physical Meteorology* (MIT Press, Cambridge, 1954).
5. Y. M. Shvarts, *Studies in Atmospheric Electricity*, V. P. Kolokolov and T. V. Lobodin, Eds. (Israel Program for Scientific Translations, Jerusalem, 1974).
6. I. M. Imyanitov and E. V. Chubarina, *Electricity of the Free Atmosphere* (Israel Program for Scientific Translations, Jerusalem, 1967).
7. J. A. Chalmers, *Atmospheric Electricity* (Pergamon, New York, 1967).
8. M. A. Uman, *Lightning* (McGraw-Hill, New York, 1969).
9. L. B. Loeb, *Electrical Coronas, Their Basic Physical Mechanisms* (U. California Press, Berkeley, 1965).
10. F. B. Salisbury, *The Utah UFO Display: A Biologist's Report* (Devin, Old Greenwich, Conn., 1974).
11. *Time* Magazine, 20 November 1978.
12. BBC World Service, 16 January 1979 (0430 UT).

Insects as unidentified flying objects: author's reply to comment; 1

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Received 8 May 1979.

With regard to the comment by Kyaw Tha Paw U,[1] I believe that he overlooks certain forces in nature. Paw U does not seem to be aware of the literature covering the phenomenon of St. Elmo's glow.

Ball lightning is accepted as a natural phenomenon, although no really good physical explanation has yet been de-

Fig. 1. Indian meal moth, *Plodia interpunctella* (Hübner). This scanning electron microscope photograph shows the proboscis and surrounding scales. Lepidoptera scales are loosely attached, corrugated, and pointed at their tips as shown by the scales laying on the proboscis. I am indebted to Thelma Carysle, USDA, for this photograph.

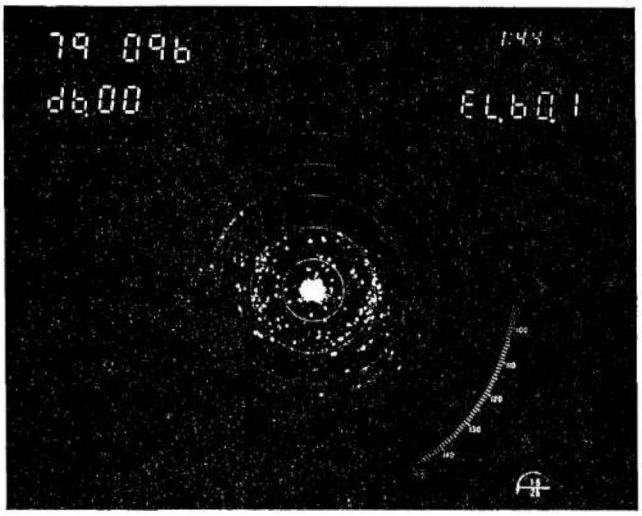

Fig. 2. The PPI scope of a 9.425-GHz (x-band) radar looking at insects over agricultural fields in Arizona (6 April 1976, 1:44 a.m.). Antenna elevation 60°; range rings 0.25 N. mi., center-ground terrain. Note that the insects tend to group and layer in the second ring (1/2 N. mi.) and can be seen dimly layered in the fourth ring (1 N. mi.). Layering and grouping of insect plankton is not at all unusual. I am indebted to Wayne Wolf, Agricultural Engineering, USDA, for this PPI photograph.

veloped. Since ball lightning floats, many physicists[2] believe the energy must be from an absorption of intense radio or other electromagnetic waves coming from outside the ball. The Soviet physicist P. L. Kapitza believes that some intense electromagnetic (nonnuclear) process feeds ball lightning. If radio waves are generated by such an electrical phenomenon, lightning cannot be pure dc as Paw U maintains. It is my personal opinion that under atmospheric conditions there is no such thing as pure dc.

Viemeister[2] quotes the great South African lightning expert, B. F. J. Schonland, as having observed lighted grass. He states, "If the thundercloud is particularly heavily charged even leaves and blades of grass may glow at the tips because of the intense ionization activity there." Surely if blades of grass and air (ball lightning) can glow in nature, insects can. No one has produced ball lightning in the laboratory (except possibly Nikola Tesla), but we have produced lighted insects under both ac and so-called dc conditions.

Further research in my laboratory (unpublished) demonstrated that once an insect is stimulated to emit St. Elmo's glow by a voltage surge of 1700–2000 V/cm, reduction of the voltage field to as low as 200–300 V/cm did not eliminate the glow. Apparently physiological gases are kept in the metastable emittance state by the well-known process of electrical hysteresis or feedback.

In regard to our quotation about blowing sand, blowing scales are far more pointed and abrasive than sand particles (Fig. 1). Entomologists understand that inhaling scales is more dangerous to the lungs than inhaling sand. Swarms of moths generate veritable storms of scales, since these structures are loosely attached to the moths (personal observations). If sand can light up by triboelectric effects, scales most certainly can—they are both dielectrics. There is little doubt that even in dry, clear weather small insects and scales driven by a fast jet stream would glow due to such triboelectric stimulation.

Swarms of insects are so usual in the upper atmosphere that entomologists[3] now speak of aerial plankton and the plankton zone (300 m and up, Ref. 3, p. 299). Insects have been taken in the plankton zone up to 4267 m (14,000 ft).[4] Over one square mile of ground in Louisiana, the air space may hold up to 93 million insects at one time.[4]

Radar researchers at NASA Wallops Island Flight Center and USDA engineers are studying insect swarms as dot angles.[5] Position plot image (PPI) scope returns (Fig. 2) demonstrate that even small species of insects tend to cluster in layers according to atmospheric conditions.

In 1969 I put insect traps on a 312-m (1200-ft) TV tower near Pelham, Georgia.[6] During migration season I obtained more insects above 76 m (250 ft) than below. I chose the spot because I knew from field experience that it should be a likely migration route. Strangely enough, 6 yr later in 1976, a Pelham resident took photographs, at the same spot, of a UFO display. *True* magazine[7] contacted me and published an article on my *Applied Optics* paper. In the magazine there was also an article on the Pelham sightings with photographs. The blobs of light look exactly like what they must be—lit-up insects.

Many species of insects are now known to ride convective storm fronts. This is a certainty in the case of the spruce budworm.[8] Such swarms may be 8–26 km (5–16 miles) long. It is quite conceivable that a voltage surge at one point in time and space might light up a portion of such a long swarm for a period and then move (or a different surge) and light up another portion of the long swarm. Such a phenomenon would give the impression to a ground observer of the light moving from point A to B at 48,279 km/h (30,000 mph) or even the speed of light.

I can make a good case for morning-bright daylight sightings being swarms of certain insect species. I do not intend to do so, for it has no practical application as does plotting insect migration routes from night sightings.

Paw U does not state his beliefs about UFOs being from an advanced extraterrestrial civilization, but my own convictions are those of Wesson.[9] In an elegant essay on the likelihood of an advanced extraterrestrial civilization, he points out that the existence of an electronic civilization equal to or ahead of our own is highly unlikely. His deduction is based partially on the fact that out of 250 billion suns in our galaxy, only 1%, or 2.5 billion, are likely to have planets climatically suited to biological life. The rest of his essay traces the history of various civilizations. He maintains that none of these civilizations, with the exception of the European, was able to sustain the high level of imaginative thought necessary to ensure their continuance. He equates the outburst of modern science with a rare combination of accidental circumstances that is unlikely to occur on other planets, at least not in synchronization with our scientific outburst. We will therefore be unable to contact any similar extraterrestrial civilization.

Based on our own work and the elegant reasoning of Wesson, I have very reluctantly come to the conclusion that the many unidentified flying object sightings are not visitors from outer space, but rather natural phenomena. Most are, no doubt, migrating or dispersing insects. Entomologists and agricultural engineers should use the Air Force UFO data to indicate placement of their radar units for migration studies.

References

1. Kyaw Tha Paw U, Appl. Opt. **18**, 2723 (1979).
2. P. E. Viemeister, *The Lightning Book* (MIT Press, Cambridge, 1972).
3. C. G. Johnson, *Migration and Dispersal of Insects in Flight* (Methuen, London, 1969).
4. B. R. Coad, *Insects Captured by Airplane and Found at Surprising Heights* (Yearbook of Agriculture, USDA, 1931).
5. C. R. Vaughn, W. Wolf, and W. Klassen, *Radar, Insect Population Ecology and Pest Management* (NASA Conf. Publ. 2070, Wallops Island Flight Center, Va., 1978).
6. P. S. Callahan, A. Sparks, J. W. Snow, and W. W. Copeland, Environ. Entomol. **1**, 497 (1972).
7. Anon., True Flying Saucers & UFO Quarterly (Spring, 1979).
8. W. R. Henson, Can. Entomol. **83**, 240 (1951).
9. R. A. Wesson, Nat. Hist. **88**, 9 (1979).

Insects as unidentified flying objects: author's reply to comments; 2

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Received 8 May 1969.

My portion of the paper[1] critized by Kyaw Tha Paw U[2] dealt with the possibility that a corona discharge from an insect swarm could be visible under natural conditions. I believe this was adequately demonstrated, although I do agree with Paw U that these conditions are rather unusual. Even though such conditions are unusual, St. Elmo's fire has been reported many times from other objects.

As Paw U points out, a dc corona discharge attenuates rapidly, causing a blinking effect which makes radiant in-