Optical Spectra, Shadow Band, Radio Frequency and Ionospheric Height Observations at the July 30, Total Solar Eclipse

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Introduction

A total solar eclipse provides an opportunity to study several interesting phenomena. Due to the rarity of total eclipses, the short time duration and the rapidly changing conditions during this short time period, many of these phenomena have not been studied thoroughly. Some of these phenomena are: 1) The optical spectrum just before, during and just after totality; 2) Shadow bands that occur a few minutes before and after totality; 3) Intensity variations of rf background at various frequencies; 4) Changes in the ionospheric layers of the earth's atmosphere.

The optical spectrum that is obtained just before and just after totality (called the flash spectrum) gives considerable information concerning the relative abundances of the elements at the sun's surface. The optical spectrum during totality, i.e., the spectrum of the corona, gives information concerning conditions such as temperature and pressure as well as relative abundances. Studies of the sun's surface and the corona are important in relationship to solar flares and the solar wind that have drastic effects upon the earth's atmospheric layers.

Shadow bands, faint light and dark bands that move across the earth's surface just before and after totality, are of considerable interest due to the fact they are probably caused by variations of some type in the earth's atmosphere (5). Previous studies of the orientation, spacing, velocity, optical wavelengths and relative intensities of shadow bands have been made in Brazil in 1966 (1), in North Carolina in 1970 (3) and in Nova Scotia in 1972 (2). The present work was an attempt to continue these types of studies.

Measurements of the variations of intensity of rf background at 3.85 MHz, 146.94 MHZ, 54.4MHz, 7.5 MHz and 550 KHz at the time of a total solar eclipse have been made previously (4). The present research continued these efforts at 5 MHz, 7.3550 MHz, 4.220 MHz and at a band of frequencies in the KHz range.

Ionospheric soundings were made during the 1973 eclipse in Surinam (4). This study showed that in the range of 3.5 to 5.5 MHz, rf reflection is changed drastically at the time of an eclipse showing that the ionosphere is profoundly affected by the lunar shadow. In the present research there was no way to make these soundings directly in the path of totality. However, records of ionospheric soundings were obtained from the Maui Field Station in the hopes that some effect could be seen at a considerable distance outside the path of totality within the penumbral track.

Equipment

To obtain optical spectra a TRAX Model 350 Field-Averaging spectrograph (from TRAX Instrument Corporation, Albuquerque, New Mexico) was attached to a Canon EF SLR 35-mm camera. This equipment was mounted on a tripod and was positioned at window 38 of the DC-9 Super 80 Hawaiian Airlines plane chartered by the Moonshadow Expeditions group (see Figure 1). The camera was set at f/2 and

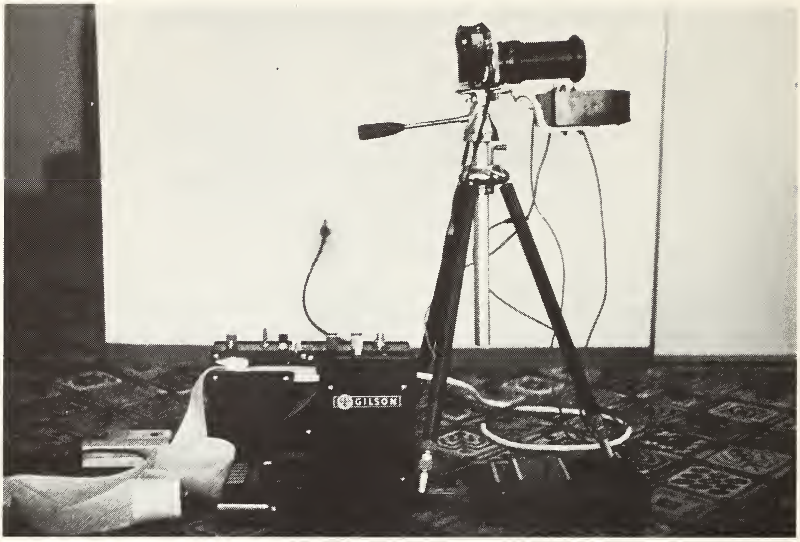

FIGURE 1. *TRAX spectrograph attached to a Canon EF SLR 35-mm camera with the photodetector system below.*

the focus was adjusted for sharp edges separating the ten different neutral density filters (a camera setting of 1.2 meters gave the sharpest edges). The ten neutral density filters range from 0.3 to 3.0, each step being a 2 to 1 ratio, i.e., one f-stop per step. This effectively provides 10 f-stops, i.e., ten different exposures at one time. The spectrograph has a wavelength range of 0.4 to 0.7 microns and a resolution of 300 Å. This instrument has just been developed by TRAX Instrument Corporation (Donald G. Carson, President) and this is the first time it has been used at an eclipse.

Shadow band studies aboard a jet aircraft presented problems such as the high speed of the airplane relative to the usually slow motion of the bands and no smooth white surface for visual and photographic work. In spite of these great difficulties it was decided that an attempt should be made to detect shadow bands on the right wing of the plane. The fact that a photograph suggesting shadow bands on an aircraft wing was published approximately ten years ago gave some encouragement. Brandon Crowe and Bill Jennings, technicians in the Department of Physics and Astronomy at Ball State, designed and fabricated a photoelectronic system consisting of six photodetectors, five of which were covered with narrow-band optical filters (see Figure 2). The uncovered photo detector was attached to a strip chart recorder while all six detectors were attached to a multiplex system (see Figure 3) which was connected to a cassette recorder. This system was "aimed" at the surface of the right wing.

Previous work has shown considerable variation of intensity of rf background during the partial phases and totality of solar eclipses, the type of variation depending upon the frequency of the rf background. This implies that even with the sun only partially covered there is a change in the ionization layers in the upper atmosphere. The most rapid electron density decay takes place in the lower

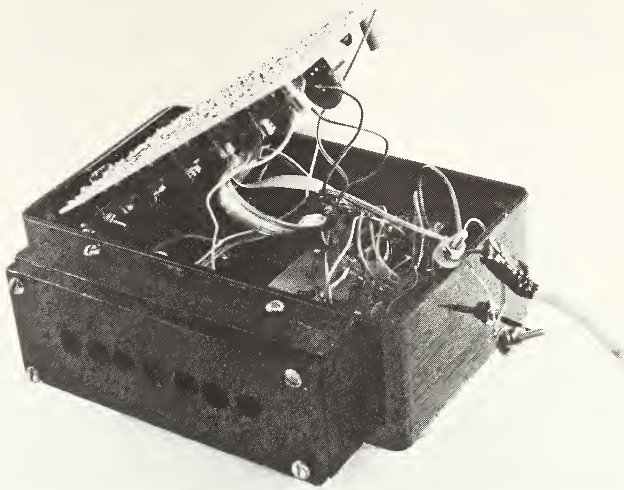

FIGURE 2. *Photoelectronic system for detecting light intensity variation (the shadow band effect) at different wavelengths.*

ionospheric region or "D" layer. The following four systems were set up to measure possible variations in rf background:

a) A Radio Shack Realistic TIMEKUBE WWV receiver, set at 5 MHz, was placed just below window number 38 with its antenna close to the window. The output of the receiver was fed into a strip chart recorder and a cassette recorder.

b) Mr. Joe F. Curado (KH6RM), Head of Avionics for Hawaiian Airlines, recorded rf background in Honolulu, using a Kenwood TS-8205 receiver (with an inverted Vee 45-foot antenna) attached to a RC-656JW/C cassette recorder. The receiver was set at 7.3550 MHz.

c) Mr. George Clark (KHGJJP), an official of the Honolulu Radio Club, recorded rf background in Honolulu, at 4.020 MHz on cassette tape.

d) A low frequency receiver, built by Bob's Electronic Service, Fort Lauderdale, Florida (advertised as a "solar flare detector") was operated the day before the eclipse, on eclipse day and several days following the eclipse. This equipment consists of a receiver tunable from 27 to 60 KHz connected to a 0-200 microampere Model 288 Rustrak recorder. As stated in the instruction manual "this receiver monitors atmospheric noises in the D ionospheric layer for sudden enhancements due to solar flares". Thus this equipment is a natural for measuring changes in the rf background during eclipses. This equipment was operated at Makaha Valley Plantation, Waianae, Oahu, Hawaii.

After the eclipse, numerical data from ionospheric sounding was obtained from Mr. David Tanaka of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Cooperating Observation Branch, Maui Field

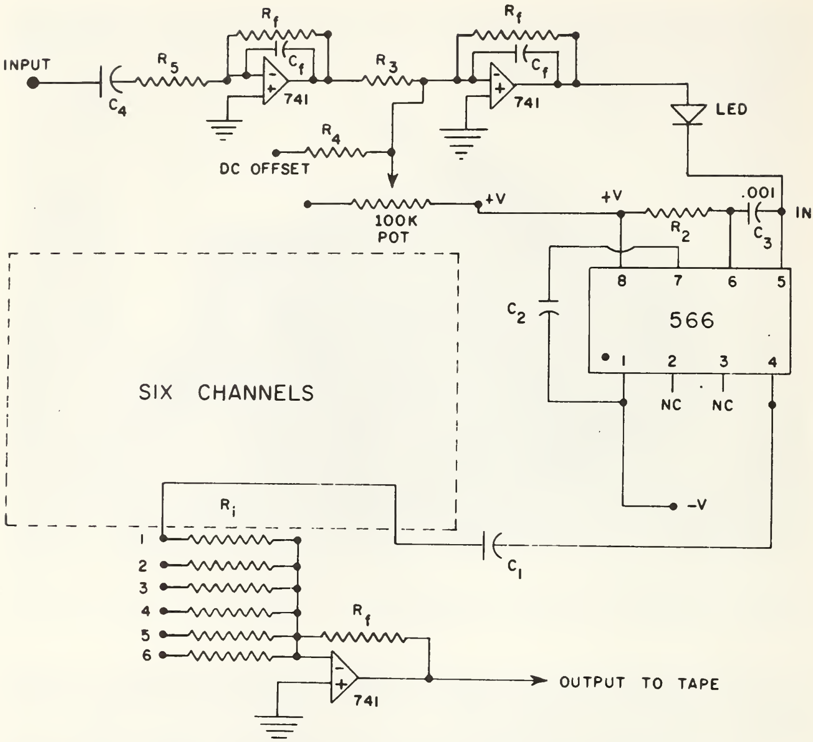

FIGURE 3. *The electronics for the photoelectronic system indicating the multiplex system, one channel shown.*

Station, Puunene, Maui, Hawaii. Although this location was several hundred miles outside the path of totality it was hoped that some "eclipse effect" could be seen in the data.

Results and Discussion

Five 15-second exposures were taken, with the TRAX spectrograph, starting approximately 30 seconds before totality. The TRI-X film shows the ten steps of the neutral density filter confirming that the 15-second exposure time, suggested by Donald Carson, was quite appropriate. Spectra are indicated on the five exposures. The spectrograph, being just developed, needs further calibration for these data to be meaningful. It is felt that this first trial is a good beginning towards more extensive use of the TRAX spectrograph at future eclipses.

As mentioned previously, the possibility of observing shadow bands aboard an aircraft is not great. An interesting visual observation, possibly related to shadow bands is reported in the following paper. The results from the photoelectronic system described above are quite complex. During the actual data taking it was noted that the part of the system consisting of the uncovered photodetector connected directly to the strip chart recorder gave very large amplitude and very high frequency signals. Superimposed on this was an overall large increase and decrease of signal with a peiod of two to three seconds. The complexity of the strip chart recording made analysis quite difficult which suggests the need for further development of this part of the system for the next eclipse. It is possible the photoelectronic system was picking up signals from other electronic instruments aboard the aircraft.

The results from the four rf experiments are as follows:

a) From 7:00 p.m. to 7:11 p.m. rf background from the Radio Shack WWV receiver, set at 5 MHz, increased approximately 50% (see Figure 4). This can possibly be explained by a decrease in the electron density in the D layer resulting in a decrease in the critical frequency. The critical frequency is directly proportional to the ionospheric electron density; at or below the critical frequency the wave is totally reflected.

b) The cassette tape recording of rf background at 7.3550 MHz, made by Mr. Joe F. Curado, was analyzed by recording it on a strip chart recorder. This recording shows some interesting variations in rf intensity. Mr. Curado reported that in his 20 years of amateur radio work he had never heard this band die down as it did two or three times during the recording.

c) The cassette tape recording of rf background at 4.020 MHz, made by Mr. George Clark was also analyzed by using a strip chart recorder. This recording shows the same variations that are in the previous recording at 7.3550 MHz.

d) The results from the low frequency receiver are quite interesting. Figure 5 shows the variation in rf background on July 29, July 30 and August 3. On all three days the pattern is quite similar during the afternoon and

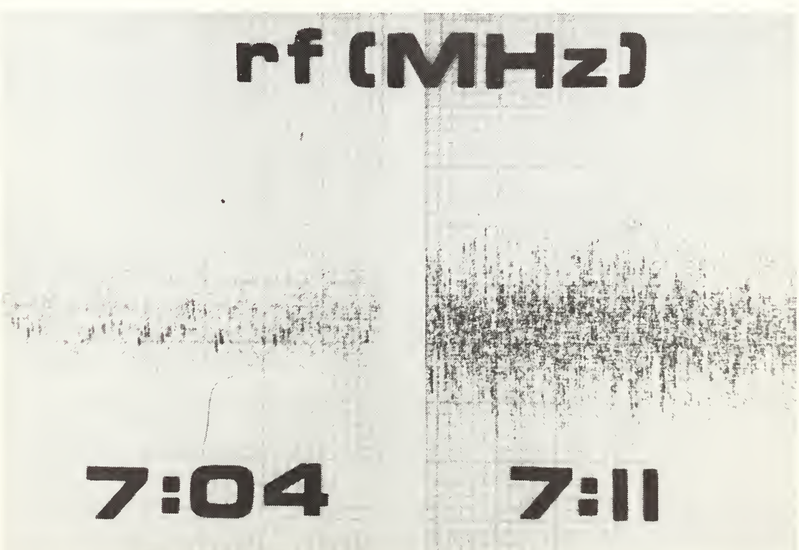

FIGURE 4. *Intensity of rf background (at 5 MHz) at 7:04 p.m. on the left and at 7:11 p.m. on the right showing a 50% increase in intensity.*

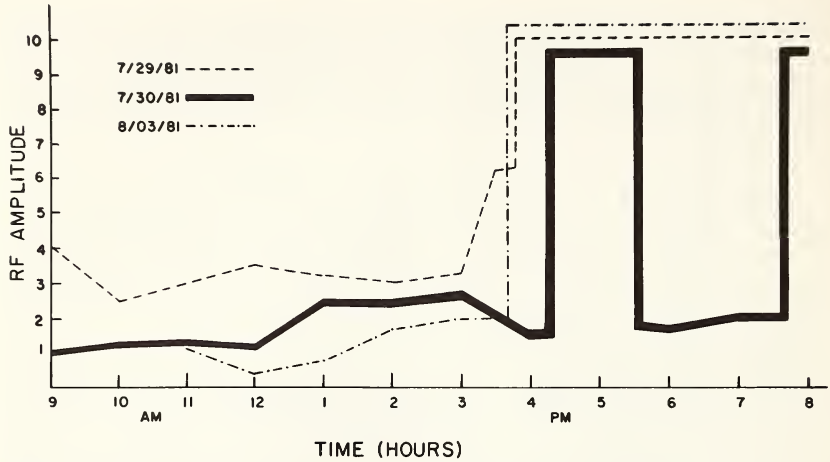

FIGURE 5. *Variation in rf intensity at low frequency on July 29, July 30 and August 3, 1981. Note the drastic decrease in rf background on eclipse day, July 30 as compared with the other two days.*

early evening. However, later in the evening the two non-eclipse day patterns are quite similar but on the eclipse day, July 30, there is a drastic reduction in rf intensity. This indicates that the eclipse has a great effect on the ionospheric D layer in the upper atmosphere (5) resulting from attenuation of solar ultraviolet emissions.

The ionospheric sounding data are quite extensive. the soundings were made several hundred miles outside the path of totality. These data have not been completely analyzed at the time of writing. However, an "eclipse effect" may be present as the D layer decay is proportional to the amount of the sun covered by the moon, and would occur within the atmospheric path crossed by the moon's penumbra.

Summary and Conclusions

The conclusions from this research are:

1) The TRAX spectrograph may be a useful tool to analyze optical spectra of eclipses. If properly calibrated this instrument will produce exposures showing relative strengths of various spectral regions. For example, such information might be useful in analysing relative intensities in the chromospheric flash spectrum. Further refinements and careful documentation of times of exposures will be needed at subsequent eclipses.

2) Shadow band detection aboard a jet aircraft is difficult. The operation of the photoelectronic system in a "real" situation was of great value for developing refinements in the equipment and developing operational procedures at future eclipses. It is felt that ground observations using this equipment, with precautions against outside electrical interference, should give very good results.

3) The results of the rf background measurements at various frequencies are of considerable interest and suggest a need for further development of equipment for eclipses in the future. The 50% increase in rf intensity

at 5 MHz over the relatively short time period of 7 minutes preceeding totality, and the drastic decrease in rf intensity at low frequencies suggest that more studies should be make at many different frequencies and over longer periods of time both before and after the total phase of the eclipse. Also it would be of interest to measure rf background at identical frequencies and with identical equipment at several locations in and out of the path of totality. Other possibilities are various coordinated effects in which an identifiable signal is sent from some distance outside the path of totality with various receivers, tuned to receive this signal, placed at various positions both in and outside the path of totality.

4) From the work in Surinam, and this project, it would appear the ionospheric soundings need to be made in the path of totality. However, it would be of extreme interest to do both simultaneously at some future eclipse.

Acknowledgments

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The logistics of placing our equipment aboard the plane and making sure it would not interfere with the navigation equipment would have been impossible without Mr. Joe Curado's assistance. He and his most able technician, Stan Okazaki, provided invaluable help.

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